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HISTORY OF THE GREAT WAR

BASED ON OFFICIAL DOCUMENTS

MEDICAL SERVICES HYGIENE OF THE WAR

VOL. II

EDITED BY

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Note.—(T) means Temporary Commission.
(T.F.) means Territorial Force Commission.

PREFACE

A GENERAL PREFACE to both volumes on the Hygiene of the War appears in the first volume, but as a special chapter on the Prevention of Typhus Fever, contributed by Colonel William Hunter and Lieut.-Colonel G. E. F. Stammers, had been arranged for in the original scheme of chapters in the second volume, some explanation for its omission is necessary in acknowledgment of the work of these officers.

It was found that in the first volume of the Diseases of the War, in the volume on Pathology and in the chapter on the Prevention of Infestation by Lice in this volume, all the facts, or at any rate all the important facts, connected with typhus fever in the war had already been recorded. It was consequently found unnecessary to introduce a special chapter in this volume on the prevention of this disease, just as the prevention of relapsing fever and trench fever also required no special chapter owing to the fact that the chapter on the Prevention of Infestation by Lice contained all that seemed necessary in connection with the subject, so far as the volumes on hygiene during the war were concerned. Acknowledgment is, however, due to both Colonel Hunter and Lieut.-Colonel Stammers for their able work in the prevention of typhus fever.

W. G. M.

October, 1922.

ABBREVIATIONS

A.A.M.C. ..	..	Australian Army Medical Corps.
A.D.M.S. ..	..	Assistant Director of Medical Services.
A.S.C. (M.T.)	..	Army Service Corps (Mechanical Transport).
C.A.M.C. ..	..	Canadian Army Medical Corps.
D.A.D.M.S.	..	Deputy Assistant Director of Medical Services.
D.D.G., A.M.S.	..	Deputy Director-General, Army Medical Service.
D.D.M.S. ..	..	Deputy Director of Medical Services.
D.G., A.M.S.	..	Director-General, Army Medical Service.
D.G.M.S. ..	..	Director-General of Medical Services.
D.M.S. ..	..	Director of Medical Services.
H.T. ..	..	Hospital Transport.
L. of C. ..	..	Lines of Communication.
M.E.F. ..	..	Mediterranean Expeditionary Force.
N.C.O. ..	..	Non-commissioned Officer.
O. i/c. ..	..	Officer in charge.
Q.M.A.A.C.	..	Queen Mary's Army Auxiliary Corps.
Q.M.G. ..	..	Quartermaster-General.
R.A.M.C. ..	..	Royal Army Medical Corps.
R.E. ..	..	Royal Engineers.
R.F.A. ..	..	Royal Field Artillery.
V.A.D. ..	..	Voluntary Aid Detachment.
Y.M.C.A. ..	..	Young Men's Christian Association.

CHAPTER I.

FOOD RATIONS IN THE UNITED KINGDOM.

FOR some years before the war the estimation of the energy value of the various foods consumed by the soldier was based mainly on the results of the analyses carried out by Atwater and Bryant in America. The analyses and calorie values of a very large number of foodstuffs were published by the United States Department of Agriculture,* and the figures, corrected up to April 1906, were used in the estimation of the food requirements for experimental marches, which were conducted under the auspices of the Army Medical Advisory Board in 1909.

An authoritative series of analyses of the common home-grown and imported food-stuffs had long been required, and the need became urgent during the war, when the army, in common with other sections of the community, was strictly rationed in 1917. Captain R. H. Plimmer, at that time Reader in Physiological Chemistry in the University of London, and a recognized authority on analytical technique, was directed to make a series of analyses for the use of the army medical authorities.

Until Captain Plimmer's figures were available, the calculations of energy values were made by using the figures given in Appendix V of the Royal Society Report on the Food Supply of the United Kingdom, and figures obtained from analyses carried out in the Royal Army Medical College. In the limited time available, such a complete set of data as those of Atwater and Bryant could not be expected. But analyses of most food-stuffs were made by Captain Plimmer, though fewer samples were necessarily taken. The aim was to arrive at an average for each group of food-stuffs, such as beef from analyses of the various joints, bread from the produce of various bakeries, fish from the group of white fish, and so on. In the case of meat the joints were separated into fat and skin and flesh and the proportions determined so as to calculate the whole. Further, the proportions of the joints of the carcase were ascertained so that the composition of any part and ultimately of the whole animal could be arrived at. The analyses were not therefore a repetition of those of Atwater and Bryant but supplementary to them. The analyses numbered about 900, and the number of weighings involved was over 20,000. Each analysis

* "Chemical Composition of American Food Materials," Bulletin No. 28.

was carried out in duplicate and the mean figure was given. The energy value of the food-stuffs was calculated for the analyses of protein, carbohydrate and fat by multiplication with the usual physiological factors, namely, 4·1, 4·1, 9·3 respectively. A full report of Captain Plimmer's work was published in book form by the War Office in 1921; it was felt that the report would be of value to other branches of His Majesty's Services and would form the basis of a common standard of food values.

Rations of the Soldier.

The scale of rations issuable to troops at home on the outbreak of war was as follows: bread 1¼ lb., meat 1¼ lb., tea ⅝ oz., sugar 3 oz., salt ½ oz., pepper $\frac{1}{36}$ oz., mustard $\frac{1}{20}$ oz., jam 4 oz., bacon 4 oz., cheese 3 oz., and fresh vegetables 8 oz.

On 22nd August, 1914, the meat issue was reduced to 1 lb. On 21st September, 1914, the sugar was reduced to 2 oz., the jam to 1 oz., the cheese to 1 oz., the bacon to 2 oz., the tea to ½ oz., the condiments remained the same, and fresh vegetables were not issued. A daily cash allowance of 4*d.* per man was, however, given in lieu of the reduced issues, and vegetables and other extras were supposed to be purchased from this grant. On 22nd May, 1915, the bread was reduced to 1 lb., and jam and cheese were not issued, but the daily cash allowance was increased to 5½*d.* per man.

The scale of rations issued on the outbreak of war was estimated to yield approximately:—

Protein.	*Fat.*	*Carbohydrate.*	*Calories.*
167 grm.	201 grm.	492 grm.	4,607

The calculation of protein, fat, carbohydrate and calories was made on Atwater's figures at that time, but if these are modified in accordance with the characteristics of British supply as given by the Food Committee of the Royal Society and by the late Professor Sir W. A. Thompson, Adviser of the Food Ministry, the total calories are reduced to 4,570. But for all practical purposes the food issued to the soldier at home in August 1914 may be taken to have had a calorie value of from 4,500 to 4,600, and was therefore a liberal diet and, judged by results of the enquiries previously carried out by the Army Medical Advisory Board, sufficient for troops under active service conditions.

The reduction in the issues of food made on 22nd August and 21st September, 1914, entailed a loss of 1,051 calories, so that on

the latter date the soldier only received 3,520 calories. But an issue of 4*d*. a day was made, and at that time, food being plentiful and cheap, it is probable that the calorie value of the food provided for the soldier was still approximately at least 4,500 calories.

The further reductions made in 1915 resulted in the calorie value of the food issued being only 2,783. In this year, however, enquiries made by Major H. P. Deasey, Inspector of the Quartermaster-General's services in the Irish Command, showed that the purchases of food made out of the money grant had a calorie value of 1,500 per man; consequently the total calorie value of the food received by the soldier was about 4,300.

On 13th February, 1916, the meat issue was reduced to ¾ lb.; the total calorie value of the food, including purchases from the money allowance, was then approximately 4,040 and so remained throughout this year. In 1917 a distinction was made between soldiers under and over 19 years of age. Soldiers under 19 received the 1916 ration; soldiers over 19, however, only received 14 oz. of bread, the calorie value of their ration was therefore only 3,893. But in 1917 there was a rise in the price of food, and it was certain that 1,500 calories of food could not then be purchased from the grant of 5½*d*. The Food Committee of the Royal Society considered that only about 1,000 calories could be obtained from the money grant, and if this were true the soldier over 19 would only be receiving food having a calorie value of about 3,400, and soldiers under 19 about 3,700. Assuming these figures to be correct, the position as regards the supply of food to troops in training at home was disquieting. The Food Committee of the Royal Society in the report dated July 1916 stated that the quantities of food-stuffs available during the period 1909–1913 were :—

	Protein.	*Fat.*	*Carbohydrate.*	*Calories.*
Per man	113 grm.	130 grm.	571 grm.	4,009

The committee considered that the minimum dietary requirements of a nation engaged on active work cannot be satisfactorily met on a less supply in the food as purchased than 100 grm. of protein, and 100 grm. of carbohydrate, equal approximately to 3,400 calories per " man " per day, a " man " being an average workman doing an average day's work. The minimum dietary requirements of an average workman could not be considered sufficient for troops in training, as the experimental marches carried out under the supervision of the Army Medical Advisory Committee showed that in these circumstances the energy expended per man was 3,989 and the

average calorie value of the food consumed 4,122. Experiences on manœuvres led the staff to recommend the Army Council to issue for the manœuvres which were to be held in 1914 a diet having a calorie value of approximately 4,200. Dr. Dunlop's observations upon convicts at Peterhead also showed the inadequacy of a ration yielding 3,500 calories for moderate work. On this ration the convicts lost weight. He found that when the diet was readjusted to yield 3,700 calories it was just sufficient to prevent loss of weight except in the case of some of the bigger men.

In these circumstances it was decided to try and determine the amount of food which the soldier had been receiving up to the end of 1917. It apparently had enabled him to meet the demands of training and remain in good health and, judged by the absence of crime, in good spirits and as happy as the constraint of military life would permit. In order to estimate the amount of food consumed it was necessary to study the diet scales in the various commands and endeavour to determine the calorie value of (*a*) the ration issued in kind, (*b*) the food-stuffs bought with the 5½*d*. allowance, and (*c*) the food bought by the soldier out of his own money. The sum of these calorie values gave the total food received by the soldier, but to know the amount consumed it was necessary to determine the loss sustained by the abstraction of fat, and by failure to utilize what was left in the cookhouse and dining-rooms. It was comparatively easy to estimate with reasonable accuracy the calorie value of food issued in kind and that purchased from the 5½*d*. grant, but to find out what food the soldier purchased out of his own money was more difficult, and special studies were made of groups of men living in camps at some distance from towns, so that the determination might have a real value. Careful analyses were made of the various kinds of food purchased in these camps, and their calorie value estimated. The following summaries show some of the results obtained:—

1. Haynes Park.	*Calories.*
Issues in kind	2,342
Purchased from money allowance	1,188
Purchased by the soldier	350
Total daily calories	3,880
Estimated loss by fat abstraction, etc.	161
Calorie value of food consumed	3,719

2. Sandwich.

	Calories.
Issues in kind..	2,201
Purchased from allowance	1,208
Allowed regimentally	111
Purchased by the soldier	350
Total daily calories	3,870
Loss from fat abstracted	32·5
Calorie value of food consumed	3,837·5

3. Crowborough Camp.

	Calories.
Issues in kind..	2,424
Purchased from allowance	1,197
Purchased by the soldier	350
Total daily calories	3,971
Loss from fat abstracted	130
Calorie value of food consumed	3,841

4. Jesuit College. A.IV. Boys.

	Calories.
Issues in kind.. / Purchased from allowance	3,428
Purchased by the boy	392
Calories in 2 oz. of extra bread	155·5
Total daily calories	3,975·5
Loss from fat abstracted	130
Calorie value of food consumed	3,845·5

5. Crowborough Camp, A.IV. Boys.

	Calories.
Issues in kind..	2,424
Purchased from allowance	1,197
Purchased by the boy	392
Calories in 2 oz. of extra bread	155·5
Total daily calories	4,168·5
Loss from fat abstracted	130
Calorie value of food consumed	4,038·5

6. Prees Heath Camp.

	Calories.
Issues in kind..	2,435
Purchased from allowance	1,198
Purchased by the soldier	298
Total daily calories	3,931
Loss from fat abstracted	65
Calorie value of food consumed	3,866

7. Bordon Camp.

	Calories.
Issues in kind..	2,402
Purchased from allowance	1,138
Purchased by the soldier	330
Total daily calories	3,870
Loss from fat abstracted	117
Calorie value of food consumed	3,753

An average of these figures gives the following results :—

	Men.	*Boys.*
Calorie value of food provided from all sources ..	3,904	4,071
Calorie value of food consumed	3,803	3,941
Calorie value of food purchased from the money allowance	1,188	1,188

The calorie values of the food provided are minimum figures; both men and boys received food from home, but it was impossible to obtain accurate figures for this supply. In some camps it was estimated that in the case of boys the food, chiefly of a carbohydrate nature, amounted to 1 oz., and in the case of men to ½ oz. daily. Against this, however, must be put the loss of fat in cookhouse and dining-room washings, estimated to amount to 20 calories a day per man. Taking all the various factors into consideration, it would appear that the food provided from all sources in 1917 was equivalent in the case of men to 3,961 calories and in the case of boys to 4,188 calories.

In a memorandum (No. 19) submitted to the Minister of Munitions, Professor L. Hill gave two tables of a hostel dietary for men. In the first table the dietary was calculated from data supplied by the management and the following results were obtained :—

	Protein.	*Fat.*	*Carbohydrate.*	*Calorie Value of Food consumed per Man.*
All meals ..	154·9 grm.	129·7 grm.	491·3 grm.	3,856

In the second table Professor Hill gave the results of his own observations at the same hostel. These were :—

	Protein.	*Fat.*	*Carbohydrate.*	*Calorie Value of Food consumed per Man.*
All meals ..	146·1 grm.	137·7 grm.	422·9 grm.	3,913

It will be seen that the food consumed by the soldier over 19 years of age had very nearly the same calorie value as that consumed by the munition worker. Boys under 19 received rather more food, but that was necessitated by the requirements of growth. Many of the boys joining the army at this period were not well nourished, and a plentiful supply of food was required to enable them to develop and carry out their military training. All the evidence seemed to indicate that men and boys in 1917 were just receiving sufficient food.

On 28th January, 1918, owing to the shortage of food supplies in the United Kingdom, an attempt was made to discriminate between soldiers doing different kinds of work. Soldiers actually employed in Home Defence, or under training for overseas, or under treatment in convalescent hospitals were

still to receive the ration issued in 1917; all other soldiers were to receive 14 oz. of bread, 8 oz. of meat, 1 oz. of sugar, and 1 oz. of bacon. Such a discrimination, however, was found to be impracticable owing to different scales of rations having to be applied to the same unit.

On 4th February, 1918, the scale was therefore changed to 14 oz. of bread, 10 oz. of meat, 1¼ oz. of sugar, and 2 oz. of bacon for all soldiers over 19. Soldiers under 19 still received an extra issue of 2 oz. of bread. On 1st May, 1918, owing to the shortage of meat, soldiers over 19 years of age received only 8 oz. of meat, the money allowance being increased to 6½*d.* per man; the boys' ration was not changed, but the 5½*d.* allowance was continued in their case. The whole ration for men yielded only 3,300 calories, as the calories to be obtained from 6½*d.* were now only about 1,170. Moreover, purchases in canteens had to be limited, so that the food received from all sources had only a calorie value of about 3,650. Deducting the loss for fat not consumed, the total calorie value of the food eaten by men was slightly under 3,500 calories, while that of the food eaten by boys was not more than 3,700.

Owing to the national calls for economy in food the military authorities sanctioned these reductions pending a full enquiry as to the work performed by troops in training. This enquiry was commenced in 1917 when the first shortage of food was experienced, as it was felt that the time might soon come when it would be necessary to give soldiers preferential treatment over the civil population. A scientific estimation was required of the food calories necessary for the work performed during the system of training, for play, rest and sleep, and for the building of body tissues. At that time the necessary data were not available. Careful estimation had been made of the calories required per kilogramme of body-weight during sleep and absolute rest in an equable temperature, and for certain classes of work such as file-cutting, pedalling a bicycle, and by soldiers marching at varying rates with various loads; but there were practically no data by which the actual work performed by soldiers during training could be estimated. The expenditure of energy for the work performed in the circumstances of military life and training cannot be economical. The constantly changing movements, the constraint of the various positions, of the load and clothing, and the performance of work at the rate and with the precision required by the instructor, and not in the manner which would naturally be selected by a worker in civil life to meet his own feelings, all militated against economical work.

As a preliminary step experts in the Western, Eastern and Aldershot Commands made careful analyses of the work during training, and they agreed that the maximum daily work might be regarded as not more than 100,000 kilogrammetres. Dividing this figure by 427 and multiplying the result by the conversion figure, the calories required for work are obtained. With untrained workers in civil life the conversion figure is usually taken as four, but as the expenditure of energy in military work is less economical a conversion figure of five was regarded as more nearly expressing the truth. Employing the figure five the calories required are 1,405, but to provide this energy in calories of food an increase of 10 per cent. must be made owing to absorption of foods consumed not being complete. About 2,500 calories being required in the daily food of a man of sedentary occupation walking two hours daily, it appeared reasonable, in the absence of exact figures, to take this figure for rest, sleep and recreation, as an ordinary recruit certainly walks more than two hours a day going to parades, meals, and during games and evening recreation.

Employing these figures, it appeared that the soldier over 19 would require daily about 4,000 calories of food, or very little in excess of what the soldier obtained from all sources.

In view of the importance of the problem the military authorities considered that, while these preliminary figures did not show in the past any great excess consumption of food by the recruit, it was desirable to have a more exact estimation made of the work done by the soldier during training. It was decided to determine by indirect calorimetry the energy expended during all the phases of the soldier's daily life. Lieut.-Colonel E. P. Cathcart and Captain J. B. Orr carried out the investigations.* The following tables give the data collected and applied for a whole week.

Weekly Energy Expenditure.

(Mature Recruit.)

					Calories.
Sleep	56 hours at	69 calories per hour		=	3,864
Meals	21 ,,	108 ,,	,,	=	2,268
Cleaning	7 ,,	130 ,,	,,	=	910
Fatigues	2 ,,	207 ,,	,,	=	414
Free time—					
(*a*) resting phase	18 ,,	75 ,,	,,	=	1,350
(*b*) active phase	18 ,,	300 ,,	,,	=	5,400
Drill	46 ,,	235 ,,	,,	=	10,810
					25,016

Daily expenditure approximately 3,574 calories.

* See Chapter IV.

Weekly Energy Expenditure.

	(*Young Recruit.*)		*Calories.*
Sleep	56 hours at 69 calories per hour	=	3,864
Meals	21 " 108 " "	=	2,268
Cleaning	7 " 130 " "	=	910
Fatigues	2 " 207 " "	=	414
Free time—			
(*a*) resting phase ..	24 " 75 " "	=	1,800
(*b*) active phase.. ..	16 " 300 " "	=	4,800
Drill	42 " 228 " "	=	9,576
			23,632

Daily expenditure of 3,376 calories.

The figures for the daily expenditure represent calories of food utilized by the body, and an increase of 10 per cent. as allowance for waste, etc., must be made in order to obtain the calories of food which should be provided.

If the figures obtained by Cathcart and Orr really represent the expenditure of energy, then in 1918, after the reduction of the food had been made, soldiers over 19 were receiving from 400 to 500 calories too little and the soldiers under 19 just enough to balance the intake and output, no allowance being made for their growth.

As soon as the diet was changed every effort was made to reduce waste, the saving of fat from food for the manufacture of munitions was discouraged and all clean fat was again made use of in preparing the soldier's food. The Quartermaster-General's Department issued diet sheets, so arranged that the cash allowance was spent in the most profitable manner. Medical officers in commands were instructed to keep a careful watch over troops in training, and where possible to weigh the men and boys at frequent intervals.

When the report of Cathcart and Orr was being compiled these diet scales were studied, and analytical figures obtained from Captain Plimmer's reports on his recent analyses of foods supplied at that time were used.

It then appeared that the army received approximately 215 calories for each penny spent and hence soldiers over 19 obtained 1,397 calories from their allowance and a total of 3,400 calories daily, while soldiers under 19 obtained 1,182 calories from the allowance and a total of 3,731 calories daily. These figures are gross value, and the corresponding values,

after making allowance for waste, would be 3,060 calories for men and 3,358 calories for boys. At this time it is probable that the average soldier over 19 years of age did not receive more than 200 calories, and the boys not more than 250 calories of food from private purchases and from home. In recognition of the fact that some provision must be made for the growth of the adolescent recruits the Inter-Allied Food Commission recommended for them an extra allowance of 200 calories per day in addition to the ordinary ration. In the case, therefore, of soldiers under 19, the total food provided from all sources, approximately 3,980 calories, sufficed for the daily expenditure of energy and for the development of the body following on the system of training. In the case of soldiers over 19, allowing 200 calories for food purchased privately and received from home, there was a deficiency of some 250 calories, which, if the figure calculated for the expenditure is correct, could only be made good by the expenditure of body tissue, and loss of weight must have occurred, combined with distinct evidence of ill-health.

Enquiries, however, made in commands during this period did not produce any evidence of ill-health, and such weighings as were made showed that approximately 81 per cent. of the recruits gained 1·38 lb. per month, 13 per cent. lost 1·07 lb. per month, and 6·6 remained constant in weight. There being no evidence of the two chief criteria of deficient feeding, Cathcart and Orr explained the discrepancy partly by the fact that the recruit did less work than was intended, the hour's drill being a nominal hour, and the actual time spent in the particular exercise only forty to fifty minutes, but mainly by the fact that the anthropometric standard selected, namely, 171 cm. and 66 kilos, was wrong. The weight of the average recruit in 1918, at least, was much below the British Association standard, the average weight of 1,808 boys on joining was found to be only 59·8 kilos; and if the height of 171 cm. can be taken as normal, then the average surface area of the recruit would be only 1·70 square metres and not 1·77, the figure used in the calculations, and consequently the expenditure of energy would be only 3,432 calories by recruits over 19 and 3,242 by boys under 19. The practical result of the investigation carried out by Cathcart and Orr was to show that, with every care to prevent loss during the preparation of food and with the best expenditure of the money allowance, the food received from all sources enabled the adult recruit's intake just to balance the output of energy and the young recruit to obtain a sufficient

surplus to permit of the increase in weight which was found to occur. The diet issued in 1918 did not indicate any excess consumption on the part of recruits and could not certainly be reduced further without modification of the system of training, which in the existing state of military operations could not be contemplated. From the strictly military point of view, therefore, the reduced diet could not be considered satisfactory.

Cathcart and Orr state that the soldier in training for the battlefield must be supplied, not only with ample food, but he ought to carry on his person reserves in the form of fat and other material, in view of the fact that any day he may be compelled by the exigencies of fighting to lose touch with his sources of supply. The man who has no reserve cannot carry on and maintain his worth as a fighter. From the administrative point the diet containing only 8 oz. of meat gave rise to considerable difficulties. The soldier during training had always been accustomed to a good meat dinner in the middle of the day and it was also desirable to provide a good breakfast. Messing officers found it an increasingly difficult problem to provide these meals in a satisfactory manner. Eight ounces of meat when cooked only represent a little over 5 oz., which was all consumed at the midday meal; there was no meat left over for breakfast or an evening meal. The scale of 2 oz. of bacon issued daily, or 14 oz. a week, provided at most four good breakfasts. Though scientific estimations demonstrated that the calories were sufficient, many soldiers, judging by the eye and by their physical sensations, considered the diet insufficient, and for this reason and for the maintenance of moral the military authorities urged that the issue of meat should be increased as soon as possible. Unfortunately this could not be done until 1919, when the strain of war was practically over.

The Feeding of Civilians and Women in Military Employment.

Immediately mobilization was declared a number of pensioners and civilians were employed for duty at various military hospitals in England. They drew rations or a ration allowance of 1*s*. 7*d*. a day, and were allowed quarters in order to meet the sudden emergency; but as the Allowance Regulations provided that pay should cover all allowances, the Army Council decided that where possible all civilians employed by the military authorities should have an inclusive rate of pay and that the issue of rations and provision of quarters should not continue.

Women cooks, whenever employed, were not affected by this decision, as a free issue of food was a normal condition of their employment.

When in January 1916 general service women and labour staff women were authorized for employment in military hospitals, head cooks and assistant cooks were to have an issue of ordinary hospital diet together with the addition of porridge and pudding. Other women, who received inclusive wages and were allowed to have dinner and tea subject to a deduction of 5*s*. a week, were also to have meals of the ordinary hospital diet with the addition of pudding. Women cooks and assistant cooks in military hospitals thus received meat 10 oz., bread 9 oz., tea ½ oz., sugar 1½ oz., milk 6 oz., butter 1½ oz., potatoes 8 oz., vegetables 4 oz., oatmeal 2 oz., and rice pudding.

From October 1916 women were employed as cooks, waitresses, and housemaids in convalescent camps, command depôts, and other special formations, and also, as a special war measure, in replacement of soldiers in officers' messes. They were given rations and provided with quarters in addition to pay. In some cases the soldier's ordinary ration was issued to them, but in May 1917 the Army Council issued an instruction to the effect that rations for women employed in these capacities were not intended to be on the same scale as the home field service ration for troops; and that the food supplied to the women should be limited to meat 6 oz., bread 11 oz., tea 1½ oz., sugar 1 oz., salt ¼ oz. daily. But in order to provide a variety of other necessary articles of diet, a daily cash allowance of 5½*d*., as for troops, was granted. At the same time the scale of diet for women cooks and assistant cooks in military hospitals was continued within the limit of that laid down for the ordinary diet for patients with the porridge and rice pudding addition, except that bread was not to be drawn in excess of 9 oz.

A later Army Council Instruction allowed women employed outside hospitals, namely, those belonging to the Women's Legion Cooking Section and the Women's Army Auxiliary Corps, a ration of meat 10 oz., sugar 1½ oz., bread 11 oz., tea ½ oz., salt ¼ oz., and as an alternative ration, 8 oz. of meat and 2 oz. of bacon in place of 10 oz. of meat. The money allowance of 5½*d*. was continued. When employed in France the following ration was allowed, meat 8 oz., bread 11 oz., tea ½ oz. or coffee 1 oz. or cocoa 1 oz., sugar 2 oz., salt ¼ oz., bacon 2 oz., jam 3 oz., vegetables 4 oz., potatoes 8 oz., rice or oatmeal 2 oz., milk 2 oz., pepper $\frac{1}{100}$ oz., mustard $\frac{1}{100}$ oz., cheese 1 oz., margarine 1 oz.

In 1918, owing to the shortage of food, the meat for those employed in the United Kingdom was reduced to 7 oz. (or to 5 oz. with 2 oz. bacon), and sugar to 1⅐ oz. The money allowance was, however, increased, and 6½*d*. a day was granted for each woman. In 1919, when a better supply of food was available, the meat was increased to 8 oz., and 1½ oz. of bacon was allowed in addition; the bread was also increased to 12 oz. At the same time the cash allowance of 6½*d*. a day was continued.

The ration remained practically the same for those employed in France, except that only 1½ oz. of sugar were allowed when sweetened condensed milk was issued. An issue of pickles three days a week was sanctioned and 1 oz. of milk could be issued in lieu of 1 oz. of cheese.

In June 1917 an important Army Council Instruction was issued concerning the rations of civilian staffs of military and war hospitals in Poor Law institutions and asylums, and civilian employees in military hospitals generally.

The Local Government Board and the Board of Control at this time were in correspondence with boards of guardians and asylum committees in regard to the question of ration scales and the Food Controller's requirements, and the Army Council considered that in the national interests every effort should be made to conform to the Food Controller's recommendations so far as civilian staffs were concerned. A fixed scale for employees could not be laid down owing to the varying character of the work performed, but the following scales A and B were recommended as guides to the food requirements of men and women workers respectively.

At this time potatoes were scarce and the Food Controller was urging economy in the use of bread and flour.

A. *Scale of Quantities sufficient to feed a Staff of* 100 *Men for one day.*

B. *Scale of Quantities sufficient to feed a Staff of* 100 *Women for one day.*

	A.	B.
Meat	75·0 lb.	56·2 lb.
Fish	18·7 ,,	18·7 ,,
Bread and flour	56·2 ,,	56·0 ,,
Sugar	9·4 ,,	9·4 ,,
Margarine	9·4 ,,	9·4 ,,
Cheese	12·5 ,,	5·2 ,,
Potatoes	25·0 ,,	20·0 ,,
Fresh vegetables	25·0 ,,	25·0 ,,
Tea, coffee or cocoa	3·5 ,,	3·5 ,,
Milk	50·0 pints	50·0 pints
Jam, syrup or marmalade	6·2 lb.	5·2 lb.
Cereals	50·0 ,,	31·2 ,,

(6167) B

Scale A was calculated to provide for each person daily, protein 145 grm., fat 135 grm., carbohydrate 402 grm., calories 3,487; and scale B, protein 114 grm., fat 111 grm., carbohydrate 339 grm., calories 2,878.

When determining the calories of food required for the male staff the military authorities considered that, in the absence of exact estimates of the work actually performed by men workers in military hospitals, it would be wise to adopt 3,500 calories in food as purchased, which is taken as the proper amount for male munition workers in Professor L. Hill's report to the Ministry of Munitions. The food required by women workers is generally considered to be 0·8 that of a man, and consequently about 2,800 calories in food as purchased was considered reasonable for the female staff.

In December 1917 the Royal Society Food (War) Committee decided that the physiological needs of the moderate male worker would be met by an average diet of 3,250 calories, and later the diets for the male staff in hospitals were arranged on this basis. The female staff were given 0·83 of the calories allowed for men.

In April 1918, owing to the shortage of meat, the scales were modified as follows:—

	Scale A.	Scale B.
Meat	14·3 lb.	14·3 lb.
Bacon	3·6 „	3·6 „
Sugar	7·2 „	7·2 „
Margarine or other fat	3·6 „	3·6 „
Fish	37·5 „	30·0 „
Bread	62·5 „	50·0 „
Flour	12·5 „	10·0 „
Cheese	15·63 „	12·5 „
Potatoes	75·0 „	60·0 „
Vegetables	25·0 „	20·0 „
Milk	25·0 pints	25·0 pints
Jam	6·25 lb.	5·0 lb.
Syrup	3·2 „	2·5 „
Cereals	37·5 „	30·0 „
Tea	2·34 „	2·4 „
Cocoa	1·56 „	1·6 „

Potatoes were then fairly plentiful and the Food (War) Committee in November 1917 issued a memorandum in which they stated they had strong evidence as to the very great value of the potato as a food and especially as to the great nutritive

value of its nitrogen-holding constituents as builders and restorers of the human body, and urged a greater use of potatoes in the home army diet and in the diet of munition workers and inmates of public institutions.

On 6th May, 1918, the Ministry of Food issued to the local food offices particulars of special scales of rations for hospitals, sanatoria, and kindred institutions. These scales were drawn up by the Food Controller after consultation with the medical officers of the Ministry of Food and of the Local Government Board, with the Food (War) Committee of the Royal Society and with an advisory committee of hospital managers. The scale for civil general hospitals was as follows, the quantities being the average per head per week, as purchased for all classes of patients taken together: meat 16 oz., poultry, game, or fish 32 oz., sardines or other dried or preserved fish 4 oz., bacon (boneless) 4 oz., bread 70 oz., sugar 8 oz., butter and margarine 4 oz., potatoes 70 oz., fresh vegetables 28 oz., milk 8·4 pints, jam 8 oz., rice 8 oz., oatmeal and pulses 4 oz., eggs 4, cheese 4 oz.

This scale also applied to the medical, surgical, and nursing staffs, and as regards the issue of meat, fish, bread, and potatoes approximated closely to the scale then in use for the male staff in military hospitals.

In December 1918, following on the improved supply of food in the country, the Army Council sanctioned the following scales A and B for male and female civilian staffs in military hospitals.

A. *Scale of Quantities sufficient to feed a Staff of 100 Men for one day.*
B. *Scale of Quantities sufficient to feed a Staff of 100 Women for one day.*

	A.	B.
Meat	14·25 lb.	14·25 lb.
Bacon	19·63 ,,	17·88 ,,
Sugar	7·13 ,,	7·13 ,,
Margarine	3·75 ,,	3·75 ,,
Fish, fresh	21·43 ,,	17·90 ,,
Bread	62·50 ,,	50·00 ,,
Flour	12·50 ,,	10·00 ,,
Cheese	9·31 ,,	6·25 ,,
Potatoes	75·00 ,,	60·00 ,,
Fresh vegetables	25·00 ,,	25·00 ,,
Milk	25·00 pints	20·00 pints
Jam	6·25 lb.	5·00 lb.
Syrup	3·00 ,,	2·50 ,,
Cereals	36·90 ,,	29·40 ,,
Tea	1·90 ,,	1·90 ,,
Cocoa	1·25 ,,	1·25 ,,

Scale A provided daily for each person, protein 94·3 grm., fat 108·9 grm., carbohydrate 445·0 grm., and calories 3,225; and Scale B, protein 78·2 grm., fat 98·7 grm., carbohydrate 363·8 grm., and calories 2,731.

Feeding of Patients in Army Hospitals.

At the commencement of the war the dieting of patients was based on the requirements of the individual patient and was to a great extent determined by the medical officer attending each case.

There were certain standard diets, such as milk, beef-tea, chicken, roast or boiled ordinary diet, and to these diets medical officers could add extras which they thought the condition of the patient required. Returns showing the food expended and the food required by each hospital were submitted by the officer in command of the hospital to the officer of the Army Service Corps in charge of supplies. In times of peace, when regular Royal Army Medical Corps officers were in charge of the military hospitals, and the returns were critically examined in the office of the Deputy Director of Medical Services of the Command, the system worked well and no great waste resulted. But when military beds were increased to hundreds of thousands and the large hospitals came under the administration of less experienced officers, it was considered desirable, in the interests of economy, to exercise more complete control over the dieting of the patients.

Consequently a War Office Economy Committee, in charge of Sir Napier Burnett, was established. This committee worked in collaboration with Colonel Sir W. H. Horrocks and Lieut.-Colonel E. P. Cathcart, who was appointed by the Director-General, Army Medical Service, as his liaison officer with the Ministry of Food. These officers were responsible for working out the diet scales which were eventually issued by the Army Council.

During the period when the supply of food in the United Kingdom was limited, Lieut.-Colonel Cathcart was able to keep the Army Medical Department informed of the various articles of food in which it was desirable to exercise economy. He also indicated the substitutes which were available.

During 1916 the feeding of patients was mainly determined on cost basis; the cost of feeding in every hospital was worked out in each command and a monthly return showing the average daily cost of subsistence was circulated. Each hospital

received a copy of the return, which showed not only its own cost but the cost of every other hospital in the command, and in this way the commanding officers were induced to investigate the cause of any excessive expenditure shown in their hospitals. If the cost of some hospitals was very low, the Economy Committee visited these hospitals and investigated the circumstances, as it was probable the patients were not getting sufficient food. Attention was also given to hospitals in which the cost was very high. The result of this work was that the cost of feeding a patient, which in the early days of 1916 was from 2*s*. to 2*s*. 4*d*., was reduced to 1*s*. 8*d*., then to 1*s*. 6*d*. and 1*s*. 4*d*. The money thus saved amounted to some millions of pounds, without interference with adequate feeding of the patients.

The committee visited almost every hospital at home and addressed the medical and nursing staffs, and Sir Napier Burnett also gave lectures on dietetics and hospital administration in the various commands.

Figures with regard to the consumption of food in twelve hospitals were obtained from the local auditor. From a study of the figures Sir Napier Burnett found that cost was not a sufficient guide as to wastage, for in one hospital, which had an apparently reasonable cost, 45 lb. of sugar per 100 men were being consumed; that is, nearly ½ lb. of sugar per man per day, whereas a reasonable amount for 100 men was only 8 to 10 lb. The cost per head revealed nothing of this. The commanding officer was unaware of the fact, and was satisfied with the average cost without going into details of items of cost. This line of investigation was followed up, and Sir Napier Burnett next obtained from the local auditors the figures of food consumption in all military hospitals in the United Kingdom for one month. These figures were analysed and placed on a basis of the food supplied to 100 patients daily. The examination of the figures showed a striking range of variation, which could not be accounted for by differences in local conditions or in the diseases from which the patients were suffering. At one hospital each unit of 100 men was found to have consumed 250 lb. of meat daily—more than double the quantity consumed during the same period by a similar hospital treating a similar class of case. This quantity of meat was supplemented by 100 lb. of bread, 20 lb. of butter, 277 pints of milk, 450 eggs, and 25 lb. of sugar, quantities sufficient to supply 7,000 calories to each patient daily. At another hospital where the figures were slightly lower than in the first, variety seemed to play an

extraordinary part. In the month there were thirty-three different kinds of meat and fish given, thirty-six different kinds of fruit and vegetables, and sixteen varieties of bread and biscuit were used.

When feeding troops the basis of calculation is the individual soldier, as all the men are supposed to be healthy and to require the same quantity of food, but such a system in a hospital leads to great waste; the requirements of the various patients vary according to the nature of the illness and the progress towards convalescence. The individual unit scale for hospital patients had to be revised, and a scale, based on a sufficiently large number of men, instituted so as to obtain a reasonable standard. The hospital unit was taken as 100 men, and a guidance scale on that basis was drawn up.

On the 6th June, 1917, officers in charge of military hospitals in the United Kingdom were directed to send monthly to the War Office a return showing the quantities of each article consumed, a separate return being furnished for officers and men on the following form.

Command ....Hospital.

..........Days of Subsistence.

Return of provisions consumed by ...... patients during monthly period ending last Friday of each month.

Article.	Quantity.	Article.	Quantity.
	lb. oz.		lb. oz.
Beef		Cheese ..	
,, steaks			
,, for beef-tea			
Mutton		Arrowroot ..	
,, chops		Barley ..	
Suet		Cornflour ..	
Beef extracts		Haricot beans	
Bacon		Lentils.. ..	
Fowls		Oatmeal ..	
Rabbits		Rice	
Tongues		Sago	
Sausage		Split peas ..	
Fish (fresh and tinned) ..		Tapioca ..	
Other meats		Other cereals ..	
Total		Total.. ..	
Potatoes		Tea	
Vegetables		Cocoa	
Other vegetables and fruits (fresh and dried)		Coffee	
Total		Total.. ..	

Article.	Quantity.	Article.	Quantity.
	lb. oz.		lb. oz.
Bread		Syrup	
Flour		Jam	
Cakes		Marmalade ..	
Total		Total	
Butter		Sugar	
Margarine			
Total			
Milk—pints		Malt liquors—pints	
,, condensed			
Eggs, new laid—No. ..		Wines and spirits—oz.	
,, fresh ,, ..			

Note.—Unless otherwise indicated, weight should be given in all cases. Days of subsistence will be obtained by multiplying the average daily number of patients by the total number of days included in the period under review.

On 12th June, 1917, an Army Council Instruction on the feeding of patients in hospital was issued, in which the Army Council considered that in the national interest every effort should be made to conform to the Food Controller's recommendations in regulating the feeding of patients in hospital. It was recognized that a fixed scale could not be laid down, but it was thought that the scale given below would form a suitable basis, any special extras for officers and men being allowed as might be necessary to meet individual cases.

Scale of Quantities sufficient to feed 100 *Patients for one day.*

Meat (including fish, bacon and sausage)	70 lb.
Bread and flour	75 ,,
Sugar	8 to 10 lb.
Margarine	9 lb.
Fresh vegetables and potatoes	60 ,,
Tea, coffee, cocoa	3 ,,
Milk	130 pints.
Jam, syrup or marmalade	5 lb.
Cereals	38 ,,
Eggs	50

The following list of cereals could be interchanged without interfering materially with the balance of the diet, as the same quantity of each possessed approximately the same calorie value :—

Split peas or beans.	Flour.	Sago.
Oatmeal.	Barley flour.	Tapioca.
Rice.	Maize-meal.	Arrowroot.

The monthly returns of the food consumed in the various hospitals when received in the War Office were put on a basis of 100 patients per day and thereafter circulated, so that each

TABLE I.

Daily Consumption of Food per 100 *Patients in Territorial Force General Hospitals during December* 1917.

Hospital.	Ranks.	Meat.	Bread.	Vegetables	Margarine.	Sugar.	Milk.	Eggs.	Tea.	Jam.	Cereals.	Cheese.	Malt Liquors.	Wines and Spirits.	Calories.
1st London General	Officers ..	127	64	149	15	23	216	233	9	13	11	2	8	57	4,775
,, ,, ,, ...	Men ..	76	72	73	8	18	193	115	4	3	10	–	7	9	3,534
2nd London General	Officers ..	137	75	106	9	16	153	92	6	11	9	2	12	14	4,187
,, ,, ,, ...	Men ..	65	59	54	7	11	137	95	2	4	5	–	3	9	2,752
3rd London General	Officers ..	127	66	128	9	25	193	106	8	9	6	4	1	4	4,316
,, ,, ,, ...	Men ..	49	46	64	6	7	121	119	3	5	9	–	–	–	2,374
4th London General	Officers ..	122	60	123	9	13	183	147	6	8	3	1	7	5	3,220
,, ,, ,, ...	Men ..	64	69	62	6	9	93	41	2	5	4	–	3	5	2,590
1st Northern General	Officers ..	104	77	85	8	11	103	49	5	5	11	6	17	13	3,554
,, ,, ,, ...	Men ..	72	73	60	7	11	105	15	3	5	21	3	1	5	3,147
2nd Northern General	Officers ..	155	72	100	7	25	133	89	10	8	17	6	13	2	4,509
,, ,, ,, ...	Men ..	65	71	49	6	6	63	4	2	5	6	–	1	1	2,424
3rd Northern General	Officers ..	95	57	83	7	10	141	69	6	9	9	3	9	–	3,234
,, ,, ,, ...	Men ..	59	72	65	7	10	82	13	3	8	9	–	2	1	2,673
4th Northern General	Officers ..	130	67	178	8	13	172	132	4	–	9	4	–	–	4,105
,, ,, ,, ...	Men ..	66	76	57	9	13	128	17	3	5	10	4	–	2	3,116
5th Northern General	Officers ..	87	74	149	5	13	95	72	4	18	17	5	5	18	3,546
,, ,, ,, ...	Men ..	73	78	57	9	14	124	7	3	4	15	2	3	1	3,282

1st Southern General	Officers ..	133	78	58	9	10	126	50	3	5	20	–	9	21	3,928
„ „ „	Men ..	71	78	63	7	10	103	39	3	6	9	–	3	2	2,631
2nd Southern General	Officers ..	104	85	116	11	14	221	123	5	8	14	6	5	14	4,442
„ „ „	Men ..	60	73	62	8	11	111	49	3	1	6	3	2	7	2,834
3rd Southern General	Men ..	81	87	67	10	8	115	24	3	7	7	1	1	3	3,240
4th Southern General	Officers ..	121	72	143	11	10	159	81	3	10	8	6	59	57	4,081
„ „ „	Men ..	55	79	64	8	12	136	97	3	6	6	–	5	4	2,999
5th Southern General	Officers ..	110	61	119	10	12	158	124	6	9	12	4	4	82	3,754
„ „ „	Men ..	71	81	67	9	11	149	71	3	2	10	2	4	12	3,380
1st Eastern General	Officers ..	89	63	86	4	10	141	133	3	5	8	4	7	23	3,155
„ „ „	Men ..	60	78	57	8	16	145	148	3	7	6	–	1	7	3,176
2nd Eastern General	Officers ..	141	72	169	12	15	155	86	6	19	13	4	10	51	4,433
„ „ „	Men ..	70	76	69	9	12	141	81	4	9	9	1	1	8	3,251
1st Western General	Officers ..	118	86	122	10	18	211	61	6	14	11	6	21	41	4,573
„ „ „	Men ..	72	76	48	7	10	125	29	3	6	13	–	–	2	3,069
2nd Western General	Officers ..	123	48	117	9	12	137	46	4	10	10	1	2	23	3,437
„ „ „	Men ..	68	74	50	8	11	128	26	3	7	8	–	4	7	3,002
3rd Western General	Officers ..	101	74	132	13	19	136	62	4	7	13	2	–	–	3,988
„ „ „	Men ..	60	83	74	9	13	116	28	3	3	6	–	–	1	2,951
1st Scottish General	Officers ..	96	61	77	6	10	195	13	3	10	15	9	1	–	3,637
„ „ „	Men ..	67	66	43	4	10	128	11	2	6	15	4	4	5	2,863
2nd Scottish General	Officers ..	88	74	80	6	8	133	34	3	11	17	1	1	–	3,350
„ „ „	Men ..	61	77	60	7	12	124	19	3	8	20	2	1	1	2,916
3rd Scottish General	Officers ..	71	75	49	6	11	101	72	2	5	19	1	1	2	3,056

hospital received a copy of the food consumption of every hospital in the country. In order to expedite this information to the hospitals a typed copy was sent to each command within five days after the 15th of the month in which the monthly return reached the War Office, and the command circulated copies to each hospital. An example of the result is shown in Table I, which gives the figures for Territorial Force general hospitals during December 1917.

All gifts of food, except personal gifts, were to be shown in the monthly return. When this was not done it often appeared that patients were not receiving a sufficient quantity of energy calories owing to the underdrawal of certain items in the scale. For instance, a small hospital of 30 beds had for some time received a gift of 3,000 eggs per week. The officer commanding accordingly cut down the allowance of animal food and in the food returns it appeared that the energy calories supplied per patient were as low as 2,400. It was only after a visit to the hospital had been made that the true state of affairs was discovered. Hospitals were also asked to show in their food returns the consumption of dripping separately from the amount of margarine used. The dripping having already been allowed for when calculating the calories contained in the meat would not be again shown in the total calories, but would appear separately from the margarine in the circulated monthly statement. Action was taken in regard to dripping, as it was found that some hospitals sold their dripping at 6*d*. per lb. and then bought margarine at 1*s*. 2*d*. per lb.

With the gradually increasing shortage of food in the country, it became necessary to revise the standard scale for 100 hospital patients. The visits of the Economy Committee to various military hospitals and the study of the returns showed that economies might be made by introducing two scales. Hospitals varied considerably in the number of acute cases requiring only a little over a basal diet of some 2,000 calories, and it was decided that there should be a minimum scale as a guide to hospitals containing a large number of acute cases, where the cooking was good and waste reduced to a minimum, and a maximum scale for other hospitals containing patients in a more convalescent state.

Accordingly, on 15th February, 1918, the Army Council cancelled the previous instruction and issued a new instruction calling attention to the urgency of the food problem and providing two scales, A and B, within which they considered

the feeding of patients in hospitals should be regulated. The scales with accompanying notes are given below.

" *Scales of Quantities sufficient to feed* 100 *Patients for one day.*

	Scale A.	Scale B.
Meat	31¼ lb.	31¼ lb.
Fish	18¾ ,,	18¾ ,,
Bacon	12½ ,,	12½ ,,
Bread and flour	69 ,,	75 ,,
Sugar	9 ,,	9½ ,,
Edible fat (margarine, suet, dripping, etc.)	6½ ,,	6½ ,,
Potatoes	50 ,,	70 ,,
Fresh vegetables	25 ,,	35 ,,
Cocoa	1 ,,	1 ,,
Milk	80 pints.	130 pints.
Syrup and jam	5 lb.	5 lb.
Cereals	7 ,,	20 ,,
Eggs	40	50
Tea and coffee	1½ lb.	2 lb.
Cheese	3 ,,	3 ,,
Approximate calorie value per patient ..	2,700	3,250

" Scale A represents minimum calorie value below which no hospital should go.

" Scale B represents a maximum calorie value which no hospital should exceed, except under special circumstances.

" In quite a number of hospitals, depending partly on the class of patients and partly on good cooking and good service, the figures in Scale A are found to be ample, but if, in the opinion of the clinical medical officers, the patients require extra feeding the quantities in Scale B are available.

" The two scales are applicable to all hospitals treating military patients, both officer patients and other ranks.

" In view of the limited supply of food in the country, officers in charge, clinical medical officers, and commandants of auxiliary hospitals are urgently requested to exercise the closest supervision over food consumption.

" Milk.—There is at present a scarcity in the supply of milk, and as this scarcity will increase until the month of May, the Food Controller requests that the greatest care be exercised in the consumption of this commodity.

" Except when purchased for medical dietetic reasons, the issue of milk should be restricted. The consumption of milk reaches a very high figure, notably in hospitals treating officer patients, due largely to patients being served with glasses of milk in the forenoon, and also with their meals. Cocoa might be substituted for this early lunch and likewise for the hot milk issued at bedtime, unless there are special medical instructions to the contrary.

" Again, the drinking of milk as a drink should be curtailed in the officers' mess.

"Meat.—Care should be taken not to overcook meat, as when this is done the meat is not only rendered less easily digested, but the calorie value of it is considerably lowered.

"Undercooking of meat is equally wasteful.

"Bread.—Bread should not be issued at dinner-time, but the amount usually eaten at this meal should be issued, along with 2 oz. of cheese, or with dripping and cocoa or soup, for supper. The suggested Scale B should not be exceeded without the written instruction of the medical officer in charge of the hospital.

"Dripping.—The dripping obtained in cooking the patients' diets should be issued in lieu of margarine as far as possible, and used for cooking purposes as well.

"Rice.—Rice for pudding should be cooked over-night, as by this means it is possible to give the patient a much larger helping.

"Potatoes.—Any potatoes left over from the dinner should be fried and issued at breakfast next morning."

Scale A is low and could only supply sufficient food for hospitals in which at least 60 per cent. of the patients were acute cases requiring little more than a subsistence ration; for the remaining 40 per cent. the scale would then provide rather more than 3,000 calories per patient. Every effort would have to be made to save every particle of food and cook it in the best possible manner.

Scale B would give similar calorie values if the proportion of convalescent patients should rise to 60 per cent. Medical officers had, however, the power to order extras for any particular patient. The medical authorities considered the scales to be somewhat too low, but they were justified in accepting them by the shortage of food then existing in the country.

The scales did not suffice for men doing physical work, as for example in orthopædic hospitals where patients were employed in workshops, or in venereal hospitals where the patients did physical work, or in hospitals where convalescent patients were employed in route marching or other physical exercises; they were only intended for patients in bed or doing no work. The Army Council Instruction was also drawn up after keeping in view the bearing that food consumption had on the shipping problem, the intention being that as much use as possible should be made of home-grown produce so as to save on imported foods.

The following table shows the saving effected by these measures in the various home commands by comparing the consumption in May 1917 with that in May 1918.

TABLE II.

Statement showing Average Consumption of Food by 100 *Patients daily for May* 1917 *and May* 1918 *in the various Home Commands.*

Period.	Command.	No. of Hospitals.	Meat, Fish, etc.	Bread and Flour.	Vegetables	Margarine.	Sugar.	Milk.	Eggs.	Tea.	Jams.	Cereals.	Cheese.	Malt Liquors.	Wines and Spirits.
			lb.	lb.	lb.	lb.	lb.	Pints.	No.	lb.	lb.	lb.	lb.	Pints.	Oz.
May 1917	Aldershot	7	83	91	91	9	19	177	94	4	8	9	—	7	16
May 1918		6	58	77	73	7	10	133	48	2	7	15	1	4	10
May 1917	London ..	27	82	76	73	10	15	139	82	4	8	11	1	3	13
May 1918		37	62	67	87	6	9	103	55	3	6	10	2	3	12
May 1917	Irish ..	32	62	94	62	9	15	164	136	4	5	13	—	5	3
May 1918		30	54	74	67	7	10	138	72	3	4	14	—	2	3
May 1917	Scottish ..	24	74	75	52	9	12	141	68	3	4	17	1	—	2
May 1918		37	52	68	72	7	9	112	42	2	4	17	2	1	4
May 1917	Northern..	55	75	84	83	9	15	136	51	4	5	10	1	3	6
May 1918		71	58	74	76	6	9	107	26	3	4	12	2	2	6
May 1917	Southern..	71	78	82	59	9	16	148	77	4	7	11	1	4	12
May 1918		95	55	72	82	6	9	110	42	3	5	14	2	4	8
May 1917	Eastern ..	81	84	90	67	10	18	164	103	4	8	12	1	3	9
May 1918		94	58	77	83	6	9	116	47	3	6	13	1	2	8
May 1917	Western ..	54	69	84	59	10	14	144	59	4	7	11	1	1	2
May 1918		102	58	72	75	6	8	115	32	3	5	12	2	1	5

The table indicates that in respect of three items alone, meat, bread, and sugar, the following savings were effected. In meat there was a reduction of approximately 5,000 tons on the year, after excluding fish and bacon. This quantity of meat represents a herd of 14,000 bullocks and the money saved was over half a million pounds. The reduction in bread was 4,800 tons, representing something like 5¼ million 2-lb. loaves saved in twelve months. The reduction in sugar was over 2,800 tons in the year, a quantity sufficient to supply the allowance then permitted by the Food Controller to a quarter of a million of people for twelve months.

An improved condition of the food supply in the country enabled the Army Council in October 1918 to authorize the following scales for 100 patients daily.

	Scale A.	Scale B.
Meat (beef)	38 lb.	38 lb.
Fish	18¾ ,,	18¾ ,,
Bacon	12½ ,,	12½ ,,
Bread and flour	75 ,,	75 ,,
Sugar	9 ,,	9½ ,,
Margarine	6½ ,,	6½ ,,
Potatoes	50 ,,	70 ,,
Fresh vegetables	25 ,,	35 ,,
Cocoa	1½ ,,	1½ ,,
Milk	80 pints.	130 pints.
Jam or syrup	7 lb.	7 lb.
Cereals	15 ,,	15 ,,
Eggs	40	50
Tea and coffee	1½ lb.	2 lb.
Cheese	3 ,,	3 ,,
Approximate calorie value per patient	3,145	3,443

These rations were more satisfactory; they enabled convalescent patients to receive food having a calorie value well above 3,500.

In the case of patients suffering from neurasthenia, patients working in orthopædic hospitals, patients convalescing from cerebro-spinal fever and venereal patients doing work, the meat issue was increased to 50 lb. per 100 men.

The scales applied to all hospitals treating military patients, both officers and men, and also to all contingents from the British Dominions.

An officer suffering from tuberculosis and treated in the special hospital at Llangammarch Wells received weekly in lieu of the amounts mentioned in the above scales, 56 oz. meat, 10 oz. butter, 8 oz. jam, and 14 pints milk.

The following scale of substitutes of one food for another, showing the percentage composition of the food, and the

relative amounts of each food required to give the same calorie value, was issued as a guide to officers in charge of hospitals.

TABLE III.

Article.	Parts per 100			Calories per oz.	Substitution amount.	Calories
	Protein.	Carbohydrate	Fat.		oz.	
Margarine	1	—	83	223	1½	334
Butter	1	—	83	223	1½	334
Dripping				287	1⅛	323
Meat	14½	—	16	65	5	325
Pork	12	—	30	117	3	351
Bacon	9½	—	69	169	2	338
Sausages (beef and fat)	8	12½	30½	106	3¼	344
Cheese	25	2½	33½	111	3	333
Fish (as purchased)						
Herring	19¼	—	7	30	11	330
Haddock, Cod	17	—	½	14	24	336
Mackerel	19	—	5½	23	14	322
Salmon	22	—	13	41	8	328
Kippers	20	—	11	53	6⅓	334
Sugar	—	100	—	113	3	339
Jam and marmalade	½	60	—	70	5	350
Golden syrup	2½	69	—	93	3¾	349
Honey	1½	74	—	108	3	324
Milk	3½	5	4	20	16¾*	335
Condensed unsweetened	9½	11	9	48	7	336
Condensed, sweetened	9	51½	13½	106	3¼	344
Dried, half cream	31	41½	16	126	2¾	346
Eggs	12	—	9	45	8†	360
Bread	9	53	1	77	4½	346
Flour	11	75	1	102	3¼	331
Oatmeal	14	66	7	116	3	348
Maize-meal (fine)	7	74	1½	95	3½	332
Barley flour	10	72	2	102	3¼	331
Pea flour	28	57	2	104	3¼	338
Peas (split)	22½	53	1½	101	3¼	328
Beans (haricot)	23	58	2	102	3¼	331
Lentils	25	55	2	102	3¼	331
Sago	—	87	—	102	3¼	331
Tapioca	—	88	—	105	3¼	341
Rice	7½	79	½	120	3¼	331
Arrowroot	—	—	—	113	3	339
Potatoes	2	15	—	25	13½	337
Carrots	¾	9	½	12	27½	330
Turnips	1	8	¼	11	30	330
Onions	1	9½	¼	13	26	338
Green vegetables	1	5½	¼	9	37	333
Tomatoes	¾	4	½	6	55	330
Fruit—						
Fresh, average	½	8	½	11	30	330
Dried, average	1¾	65	2½	85	4	340

* Fluid ounces. † 4 Eggs.

In 1919, owing to the great increase of convalescent patients in the hospitals, the scales of rations allowed in 1918 proved insufficient and requests were received from commands, and especially from Dominion contingents, for an increase in the rations. The deputy directors of medical services of commands were consequently asked to determine the proportion of convalescent to acute patients in their various hospitals. The returns showed that for practically all military hospitals in the United Kingdom the proportion of convalescent patients had risen 80 to 90 per cent.

In these circumstances a ration scale such as Scale A, providing only 3,145 calories per patient, was obviously useless and a new ration scale for 100 patients daily was sanctioned by the Army Council. The following was the scale then introduced:—

Meat (beef)	50½ lb.
Fish	18½ „
Bacon	12½ „
Bread and flour	87½ „
Sugar	9½ „
Margarine	6½ „
Potatoes	70 „
Fresh vegetables	35 „
Cocoa	1½ „
Milk	130 pints
Jam or syrup	13¼ lb.
Cereals	15 „
Eggs	50
Tea and coffee	2 lb.
Cheese	4¾ „
Approximate calorie value per patient	3,832

Diets in Canadian Military Hospitals in England.

The food supplied to the Canadian military hospitals in England was under different control from that of the military hospitals under War Office administration. The problems of dieting patients in them were specially considered by the Canadian authorities, and the results are of interest in showing how the difficulties were overcome in a manner which had the effect of putting an end to complaints of insufficient or unsuitable diets.

In 1915 there was no centralized control of the purchasing of food, nor was there any definite limit placed the upon

quantities of food-stuffs which might be issued by Canadian hospitals for the dieting of patients. In a broad way issues were restricted to the quantities laid down in regulations for the allowances of the army, and supplies were purchased locally by the hospital authorities at the best rates that could be obtained in the neighbouring markets.

The hospitals then established at Taplow, Bromley, and Monks Horton purchased such supplies as were deemed necessary and forwarded tradesmen's accounts at the end of the month to the Chief Paymaster, by whom the bills were paid. This procedure continued in force until the end of 1915, when a Hospital Supply Department was established at Shorncliffe under the supervision of the Director of Supplies and Transport. At the same time a Purchasing Department was set up, and these two departments, with the active co-operation of the medical corps, devised a system for the centralized control of food purchases. In consequence the privilege of purchasing food-stuffs in local markets was either withdrawn or greatly limited, and from the beginning of 1916 hospitals obtained the necessary supplies in part from the nearest Army Service Corps depôt, whether British or Canadian, and in part from the food supply warehouse established at Shorncliffe.

During this period officers in charge of hospitals were encouraged in the economical administration of food, but no control was exerted by the Hospital Supply Department in so far as laying down scales of diets or supervising the conservation of waste was concerned.

In the early spring of 1917 the increasing difficulty of accumulating sufficient quantities of food by purchasing in the open market became acute, and from 1st February, 1917, the entire supply of food-stuffs, with the exception of a few staple commodities such as bread, meat, sugar, tea, bacon and milk, was obtained from the Army Canteen Committee.

With some modification the Canadian Hospital Supply Department continued to supervise the supply of food to the hospitals. This department maintained a cost record of hospital dieting, but beyond calling attention to excessive cost made no effort to interfere with the administration of the food supplied once delivery had been accepted by the proper hospital authorities.

At the end of June 1917 the duties of the Hospital Supply Department, in so far as accounting and the general supervision of supply administration were concerned, were transferred to the medical services. Provision was immediately made

for a survey of the situation, with the result that a series of periodic inspections was begun, resulting, through the co-operation of hospital authorities, in a vast improvement in the efficient and economical administration of food supplies within the hospitals.

During the remainder of 1917 great improvement was effected in the cooking and serving of attractive diets, allowances still being governed by Army Regulations, which had been more or less carefully followed since the beginning of the war. A series of weekly dietaries, based on Army Regulations, was periodically submitted by the hospitals, and the careful examination of these reports with attendant criticism and discussion resulted after a time in the standardization of an ordinary diet without any sudden drastic revision such as might disturb the arrangements for diets in any hospital.

During 1917 and the early part of 1918 the problem of accumulating sufficient quantities of food-stuffs became more and more acute, and to meet this situation the minimum and maximum scales issued by the Army Council for British hospitals were made applicable to the Canadian hospitals.

The Army Council Instruction was a complete departure from regulations which had previously been in force. Instead of considering the individual requirements of each patient in drawing up a scale of issues, it was held that in the feeding of sick men the average requirements of large numbers furnished a safer basis of computation. Allowances were fixed at sufficient quantities to meet the average requirements of 100 patients, on the understanding that issues would be made by the steward in bulk, and that distribution would take place in the main kitchens and in the service kitchens.

On investigation it was found that about 11 per cent. of all cases in hospitals treating bed patients were on milk diet. An effort was then made to divide the allowance per 100 patients in such a way that approximately 90 per cent. of the patients would consume the entire meat allowance, while the other 10 per cent. would have a sufficiency of milk and milk puddings. This resulted in the drawing up of a standard menu, which became effective early in April 1918. This menu was based on both Scales A and B of the Army Council Instruction and was sufficiently under the maximum allowance to provide for a limited issue of ward extras as well as a margin of safety to prevent, where possible, an over-issue of the maximum allowance.

In comparison with the maximum laid down in Scale B, the value of the ordinary diet for a patient was as follows :—

Value of Standard Menu.

	Protein.	Fat.	Carbo-hydrate.	Calories.
	grm.	grm.	grm.	
Standard menu	100·99	118·30	407·19	3,266
Reserve	5·79	14·06	13·49	124
Maximum allowance ..	106·78	132·36	420·68	3,390

The standard menu provided considerable variety but was subject to adverse criticism on the grounds of its having a deficient meat content, too many fish meals, too many cereal dishes, and too little sugar and jam. The shortage of meat was generally remarked but gave the greatest cause for complaint in hospitals where the majority of patients were walking about or doing physical exercises. The objection to the quantity of fish and cereals in the menu was to some extent anticipated, for previous experience in the feeding of Canadians had demonstrated that neither of these foods is popular as a main article of diet. This had been found to apply not only in the feeding of sick men, who might be expected to offer some objection, but to the personnel of staff messes as well.

Unsatisfactory methods of preparation employed in hospital kitchens were to some extent responsible for the complaint, but even when these difficulties had been overcome it was still reported that the standard menu gave cause for adverse criticism on the grounds of deficient nutrition. For the purpose of testing the truth of this complaint seventeen patients at one hospital were kept under observation, twelve of them for a period of fourteen days from the date of admission and five of them for a period of twenty-one days from the date of admission. At this hospital the patients were under special treatment, and in addition to ordinary walking exercise, they were placed on a course of light calisthenics, with the result that all but two of them lost weight.

These patients were under observation during the period 11th April to 13th May, 1918. They were carefully weighed on admission and again at the end of the period of observation, the results being as follows :—

TABLE IV.

Effect of reduced Diet.

	Weight on admission.	Weight.	Loss.	Gain.
Section I.	lb.	*At end of* 14 *days* lb.		
A	144·25	141·50	2·75	—
B	164·00	162·50	1·50	—
C	154·50	156·00	—	1·50
D	154·00	153·00	1·00	—
E	126·00	125·00	1·00	—
F	156·00	152·50	3·50	—
G	141·00	140·00	1·00	—
H	132·00	131·00	1·00	—
I	135·00	133·00	2·00	—
J	141·00	136·75	4·25	—
K	167·00	162·50	4·50	—
L	140·00	136·50	3·50	—
Section II.		*At end of* 21 *days*		
A	142·00	144·00	—	2·00
B	154·00	151·25	2·75	—
C	152·00	150·00	2·00	—
D	137·00	136·00	1·00	—
E	142·50	141·50	1·00	—

Further examination of results obtained confirmed the contention that the standard menu provided a deficient diet for sitting-up and convalescent patients. All hospitals co-operated in giving this reduced dietary a fair trial during April, May and June 1918. The conclusion was then reached that, while the maximum scale laid down in the Army Council Instruction might be sufficient for bed patients averaging ten sleeping and fourteen waking hours in bed each day, the calorie value of the diet was not sufficient to meet the requirements of ordinary routine in Canadian hospitals, where a large percentage were able to be up and about the wards and grounds.

In the case of convalescent and special hospitals where the patients were given physical or remedial exercises the diet laid down was admittedly too low; while the opening of a special hospital for the treatment of tuberculosis called for special consideration.

As a result three scales of diet, based on the average requirements of one hundred patients for one day, were made effective from 1st July, 1918, and found satisfactory. They were made applicable as follows :—

Scale A : Maximum diet. Tuberculosis patients.
Scale B : Full diet. Convalescent and special patients undergoing physical training.
Scale C : Reduced diet. Patients undergoing active treatment in primary and special hospitals.

The quantities considered sufficient to feed 100 patients for one day with the nutritive ratio and calorie value of the component parts in each class of diet are shown in the following table.

TABLE V.

Scales of Quantities sufficient to feed 100 *Patients for one Day.*

SCALE A.

Article.	Weight.	Protein.	Fat.	Carbo-hydrate.	Calories.
	lb.	grm.	grm.	grm.	
Meat	75·00	4,455·00	8,481·06	—	95,850
Fish	18·75	851·25	84·37	—	4,275
Bacon	15·00	645·00	4,083·00	—	40,620
Bread	100·00	3,552·52	214·40	24,720·00	117,914
Sugar	17·50	—	—	7,778·75	31,885
Margarine	6·25	—	2,368·75	—	22,031
Other fats	4·75	—	—	—	—
Potatoes	70·00	555·80	32·20	6,668·00	29,890
Fresh vegetables ..	35·00	120·75	23·80	633·50	3,325
Milk (pints)	400·00	7,344·00	8,096·00	10,720·00	150,000
Syrup	1·75	19·05	—	550·10	2,327
Jam	10·75	15·05	—	3,369·05	13,867
Cheese	5·00	567·00	680·00	56·50	8,885
Cereals	35·00	1,771·00	504·50	11,770·50	58,345
Tea and coffee ..	2·50	—	—	—	—
Cocoa	2·00	181·33	235·73	385·60	4,517
Eggs (number) ..	250	1,275·00	1,012·50	—	14,625
Total	—	21,352·75	25,616·31	66,652·20	598,356
Daily average per patient	—	213·52	256·16	666·52	5,983

SCALE B.

Article.	Weight.	Protein.	Fat.	Carbo-hydrate.	Calories.
	lb.	grm.	grm.	grm.	
Meat	50·00	2,970·00	5,654·04	—	63,900
Fish	18·75	851·25	84·37	—	4,275
Bacon	12·50	537·50	3,402·50	—	33,850
Bread	75·00	2,664·40	160·80	18,540·00	88,436
Sugar	9·50	—	—	4,222·70	17,309
Margarine	4·18	—	1,584·22	—	14,734
Other fats	3·62	—	—	—	—
Potatoes	70·00	555·80	32·20	6,668·20	29,890
Fresh vegetables ..	35·00	120·75	23·80	633·50	3,325
Milk (pints)	130·00	2,386·80	2,631·20	3,484·00	48,750
Syrup	1·00	10·88	—	314·34	1,330
Jam	4·00	5·60	—	1,253·60	5,160
Cheese	3·00	340·20	408·00	33·90	5,331
Cereals	35·00	1,771·00	304·50	11,770·50	58,345
Tea and Coffee ..	2·00	—	—	—	—
Cocoa	1·00	90·66	117·86	192·80	2,258
Eggs (number) ..	50	255·00	202·50	—	2,925
Total		12,559·84	14,605·99	47,113·54	379,818
Daily average per patient		125·59	146·05	471·13	3,798

SCALE C.

Article.	Weight.	Protein.	Fat.	Carbo-hydrate.	Calories.
	lb.	grm.	grm.	grm.	
Meat	45·00	2,673·00	5,088·36	—	57,510
Fish	18·75	851·25	84·37	—	4,275
Bacon	12·50	537·50	3,402·50	—	33,850
Bread	75·00	2,664·40	160·80	18,540·00	88,436
Sugar	9·50	—	—	4,222·70	17,309
Margarine	4·18	—	1,584·22	—	14,734
Other fats	3·62	—	—	—	—
Potatoes	70·00	555·80	32·20	6,668·20	29,890
Fresh vegetables ..	35·00	120·75	23·80	633·50	3,325
Milk (pints)	130·00	2,386·80	2,631·20	3,484·00	48,750
Syrup	1·00	10·88	—	314·34	1,330
Jam	4·00	5·60	—	1,253·60	5,160
Cheese	3·00	340·20	408·00	33·90	5,331
Cereals	30·00	1,518·00	261·00	10,089·00	50,010
Tea and coffee ..	2·00	—	—	—	—
Cocoa	1·00	90·66	117·86	192·80	2,258
Eggs (number) ..	50	255·00	202·50	—	2,925
Total		12,009·84	13,996·81	45,432·04	365,093
Daily average per patient		120·09	139·96	454·32	3,650

These scales became effective at the beginning of July 1918, when complaints of deficiency in the allowances ceased.

A system of weekly returns of actual consumption in all hospitals was then instituted, and while a few commodities were at first found to be issued in excess of the scale, it was noted that the tendency in all hospitals was to under-issue the maximum quantity allowed. Representative hospitals, where each scale of diet was in use, were kept under close observation, and it was found at the end of August 1918 that the average of actual issues showed considerable reduction in hospitals subsisted on Scale A and Scale C, while hospitals engaged in physical training under Scale B closely approximated the maximum allowance.

A comparison of authorized and actual consumption by a patient daily during the period of observation is as follows :—

TABLE VI.

	Protein.	Fat.	Carbo-hydrate.	Calories.
	grm.	grm.	grm.	
Scale A—				
Maximum allowance ..	213·52	256·16	666·52	**5,983**
Actual consumption ..	168·35	210·86	609·23	**5,142**
Scale B—				
Maximum allowance ..	125·59	146·05	471·13	**3,799**
Actual consumption ..	118·68	148·64	450·77	**3,710**
Scale C—				
Maximum allowance ..	120·09	139·96	454·32	**3,650**
Actual consumption ..	106·98	138·57	408·87	**3,398**

It was considered that Scales A and B afforded ample allowances for the purpose intended. The dieting of patients under active treatment, however, required special attention. It was noted that in the actual carrying out of the dieting of patients under Scale C an under-issue of protein and carbohydrate had resulted in the loss of approximately 250 calories per patient daily. After Scale C diet had been in use for nearly two months, the question of arriving at the best scale of diet for Canadian patients under active treatment was discussed with the Army Medical Department at the War Office. Based on the metabolic requirements of patients subsisted in the primary hospitals on war-time food-stuffs, as calculated in the laboratories of the Royal Army Medical College, it was considered that the dieting

needs of the average patient of this class were being met. The maximum daily requirements suggested by the War Office had been very closely approximated in Canadian hospitals subsisting patients under Scale C diet, as is shown by the following comparison between the two.

Comparison of Active Treatment Diet.

	Protein.	Fat.	Carbo-hydrate.	Calories.
	grm.	grm.	grm.	
British	108·75	139·46	414·23	3,443
Canadian	106·98	138·57	408·87	3,398

In providing for the efficient feeding of hospital patients many contributing factors were considered. It was, of course, essential that food should be thoroughly cooked, attractive in appearance, and served quickly at a proper temperature. Steps were taken to standardize the work of the service kitchens. In some instances, where large numbers dined together in a common hall, difficulty was experienced in placing hot food on the patient's plate.

The solution of this problem was found in the use of a specially designed self-serving tray. Patients were seated at small tables in groups of six or eight, and practically the entire meal for each group was served in one large water-jacketed container, divided into five compartments, holding soup, meat, potatoes, a second vegetable and pudding. This tray was supplied with a lid and the necessary serving utensils. It was found that hot food could be kept at a proper temperature for one hour from the time that each tray was filled and the lid fixed in position, thus making it possible to place hot food on each group table before the patients were admitted to the dining hall. As soon as they were seated, one of the patients in each group would serve the soup and the other courses in succession, each article of the diet being placed on the patient's plate at practically the same temperature at which it had left the service kitchen thirty minutes before.

The changes effected resulted in a very noticeable improvement in the feeding of patients. The dining-rooms were made bright and cheery; confusion in the seating and serving of patients was eliminated; food was placed on the tables in an attractive and appetizing manner, and the patients ate well.

Both the constitution of diets and the control of diet distribution had a direct bearing upon the question of eliminating waste.

The cost of feeding patients in Canadian hospitals during the four months ending August 1918 was as follows :—

TABLE VII.

Cost of Diets in Canadian Hospitals.

Average daily cost for each patient, May to August 1918.
(Figures represent pence to three places of decimals.)

Name of Hospital.		May.	June.	July.	August.
Tuberculosis Hospital,					
Lenham.. ..	Scale A	45·822	42·597	51·596	51·206
Bromley	Scale B	24·070	20·751	24·091	24·782
Bearwood	,,	20·859	20·644	21·247	21·239
Matlock	,,	24·442	25·645	25·038	25·772
Monks Horton ..	,,	18·030	17·144	16·995	— *
Witley	,,	24·174	24·559	26·558	26·106
Epsom	,,	15·250	15·752	16·017	16·500†
Bexhill	,,	15·216	15·720	16·239	16·500†
Basingstoke ..	Scale C	18·789	19·173	24·036	26·905
Kirkdale	,,	23·121	16·137	19·180	21·156
Moore Barracks ..	,,	23·122	24·926	26·551	26·441
Bramshott ..	,,	17·152	17·571	20·051	22·720
Eastbourne ..	,,	17·905	18·437	20·430	23·153
Taplow	,,	22·039	22·246	23·794	25·123
Orpington ..	,,	19·110	22·829	21·645	23·140
Bushey Park ..	,,	17·995	18·008	19·380	20·779
Buxton	,,	17·221	19·639	21·226	24·043
Buxton Red Cross	,,	18·269	21·679	23·867	25·348
Westcliff	,,	20·644	22·334	23·795	23·333
Etchinghill ..	,,	14·702	16·042	18·154	20·209
Hastings	,,	21·497	22·185	26·054	26·494
Total	Scale B	142·041	140·215	146·185	130·899
Average.. ..	,,	20·292	20·032	20·888	21·817
Total	Scale C	251·566	261·206	288·163	308·844
Average.. ..	,,	19·351	20·093	22·166	23·757

* Closed 31st July, 1918.
† Full messing allowance subject to reduction.

The increase in the cost of July over June was due to the introduction of expanded scales of diets in the latter month. The increase in August over July was not due to this cause, nor was it due to any appreciable increase in market prices.

The feeding of both soldier personnel and women employed in the hospitals was specially considered. A large number of

the soldiers on the staffs of hospitals, both non-commissioned and other ranks, were low category men who had been returned to England, in many cases after being disabled to some degree in the fighting zone. These men were subsisted on a scale of rations approximating the allowance to British soldiers in home areas and slightly below the scale, Scale B, authorized for convalescent patients undergoing physical training. This allowance was known as Scale D and each ration had a gross value of 108·84 grm. protein; 121·10 grm. fat; and 430·25 grm. carbohydrate, or 3,328 calories.

In the feeding of members of the Q.M.A.A.C., V.A.D., and other women employed in Canadian hospitals the daily allowance was based upon the scale of issues laid down by the British military authorities. The cost of feeding hospital personnel was approximately 1*s*. 6*d*. per head daily.

CHAPTER II.

FIELD SERVICE RATIONS.

THE rations issued to troops in the several theatres of war varied considerably to meet the special requirements of locality and climate as well as the needs of the different nationalities and races employed in auxiliary services. Consequently the scales of food are best considered in detail according to the particular theatre of war to which they were made applicable.

ON THE WESTERN FRONT.

At the beginning of the war the ration issued to all troops of the British Expeditionary Force in France was that laid down in Allowance Regulations.

This ration, together with its energy value in calories, is given in Table I. During the course of the war it was modified from time to time in various ways.

The transition from a war of movement to the more settled conditions of trench warfare, the differentiation and specialization of work in all branches of the army, and variations in local conditions necessitated alteration both in the nature and the amounts of the constituents of the ration.

The influence of climate and the season of the year also called for appropriate modifications, and from time to time, in the interest of the health of the troops, changes were made in consequence of special medical considerations.

Improvements were effected in existing constituents of the ration and new constituents were introduced when advantage in respect of palatability and nutritive properties made it appear that such innovations were desirable.

The ease or difficulty with which various supplies could be obtained had also to be taken into consideration and although every endeavour was made to avoid changes in the ration on this account such alterations had to be introduced from time to

time. Fortunately, however, it was possible in the majority of cases to effect the alterations without any serious sacrifice of variety, palatability, or nutritive value.

Recommendations and suggestions for alterations in the ration originated from several sources. In many cases changes were suggested by commanders of units or formations, to meet the requirements of local conditions, climatic influences, or special work. From time to time the Director of Supplies suggested alterations or additions to the ration according to the supplies which he had in hand, or in consequence of information furnished to him by the War Office regarding new types of food, improvements in existing constituents of the ration, or the shortage of various articles of diet. In many cases it was possible to adopt such suggestions with advantage, and in others without detriment to the ration; occasionally the suggested alterations were considered unsuitable and were not adopted.

The medical authorities exercised a constant vigilance over the adequacy and suitability of the diet for the varying needs of the troops and appropriate recommendations were made by the Director-General of Medical Services in France to the Quartermaster-General at General Headquarters as occasion demanded, all suggestions for modifications in the ration, from whatever source, being submitted to the former for his opinion as to their desirability on medical grounds.

In regard to technical considerations, the advice of the A.D.M.S. (Sanitation) on the staff of the D.G.M.S. was available and all matters relating to diet were referred to him by the D.G.M.S. for an opinion.

When a considerable or important alteration in the ration was proposed or when the consolidation of a number of minor alterations made at different times was contemplated, the matter was considered at special conferences presided over by the Q.M.G. and attended by the A.D.M.S. (Sanitation) as representative of the D.G.M.S. As the campaign proceeded the various general routine orders, which from time to time had been issued altering the ration or amending existing orders, were for simplicity consolidated in a ration pamphlet which was issued with a general routine order. This ration pamphlet contained all the various rations in force at the time of its issue and greatly facilitated reference. As occasion demanded, amendments to the ration pamphlet were published in general routine orders, and when these in their turn became too numerous and complicated for ready reference, they were

embodied in a revised ration pamphlet issued on 9th November, 1918.

Meat.—The ration of meat consisted at the outbreak of war of $1\frac{1}{4}$ lb. of fresh or frozen meat per man per day or 1 lb. (nominal) of preserved meat,* which is the equivalent in nutritive value of $1\frac{1}{4}$ lb. of fresh or frozen meat. Early in the campaign when the war of movement had resolved itself into stationary warfare it became apparent that this was excessive and led to waste. The ration was issued as a mixture of frozen and preserved meat in the proportion of 75 per cent. frozen meat and 25 per cent. preserved meat, *i.e.*, 16 oz. fresh or frozen meat and 3 oz. preserved meat per man, and it was in this latter constituent that waste was apparent. The waste was due in part to the distaste for preserved meat when issued day after day for prolonged periods. To minimize this it was proposed to reduce the meat ration to 1 lb. per day and effect was given to this proposal by a general routine order. The usual proportion of 75 per cent. fresh or frozen meat and 25 per cent. preserved meat was maintained, so that the meat ration then consisted of 75 per cent. of 1 lb. frozen meat = 12 oz., and 25 per cent. of 9 oz. of preserved meat = 2·25 oz. The reduction in the meat was compensated for and variety introduced by the issue of condensed milk on the scale of one tin of milk (16 oz.) to eight men. By a later order the milk was reduced to one tin for sixteen men daily, and still later augmented to one tin for twelve men daily.

The monotony of the daily issue of preserved meat was further relieved by the issue of a meat and vegetable ration in lieu of a portion of the preserved meat. The effect of this was to make every 100 lb. of the meat ration (*i.e.*, meat ration for 100 men) consist of 75 lb. of frozen meat and 25 rations of preserved meat (1 lb. nominal each) on five days a week, and 75 lb. of frozen meat and 25 rations of meat and vegetable rations (each containing 22 oz.) on two days weekly. This would mean a quarter of a tin, or 5·5 oz., meat and vegetable ration for each man on two days a week. The actual consumption of the meat and vegetable ration would not necessarily occur on the day of issue but could be distributed as was found convenient throughout the week.

In March 1916, in view of a probable temporary shortage in the supply of frozen meat, the War Office suggested that as a precautionary measure a portion of the issue of frozen meat

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*** Preserved meat is packed in tins and designated 1 lb. (nominal) although each tin contains only 12 oz. of meat.**

might be replaced by a new element in the ration, namely, pork and beans. Samples of this article of diet were supplied and were submitted to the Base Hygiene Laboratory, Boulogne, for analysis and determination of energy value. It was eventually decided to modify the meat ration and to introduce pork and beans as a portion of this ration and effect was given to this decision by a general routine order which amended the meat ration as follows:—

60 per cent. frozen meat (at 1 lb.);

25 per cent. preserved meat (at ¾ lb. nominal);

15 per cent. meat and vegetable rations (three days out of seven);

15 per cent. pork and beans, *i.e.*, 33½ tins per 100 men (four days out of seven).

In other words, the daily meat ration now consisted of frozen meat 60 per cent. of 16 oz. = 9·6 oz., and preserved meat 25 per cent. of 9 oz. = 2·25 oz.

As time went on the position in regard to supplies of frozen meat did not improve, and in 1918, at the urgent request of the War Office, the field service ration was as a whole further modified to meet the situation in regard to food supplies generally. So far as meat was concerned a slight reduction in frozen meat was effected and was compensated for by an increase in the issue of preserved meat. The inclusion of meat and vegetable and pork and beans in the meat ration had been found to cause some confusion and misunderstanding, and as there appeared to be no likelihood of discontinuing the use of these commodities and returning to the original meat ration, it was decided for the sake of simplicity and to avoid misunderstanding to cease the issue of meat and vegetables and pork and beans as integral portions of the meat ration and to regard them as separate elements of the general ration. Accordingly the revised pamphlet of 9th November, 1918, was issued. In it the meat ration was modified in the direction stated above, the amounts of frozen meat and preserved meat being specifically mentioned and not given as alternatives. The amounts of meat and vegetable and pork and beans were also stated independently of meat and the former was removed at this time from the ration given to men on the lines of communication.

The ration of frozen meat consisted of beef and mutton although the former predominated, as it could be transported with a greater saving of space than mutton.

The quality of the meat ration was uniformly excellent. The frozen meat supplied was of high grade, and, in spite of difficulties in transport which were unavoidable, the meat almost invariably reached units in good condition. Occasionally delays on the railways resulted in consignments of beef becoming unfit for issue, especially in summer-time, but these occurrences were rare. Preserved beef was almost invariably in good condition when it reached units and the amount condemned for unsoundness, as evidenced by blown or damaged tins, was negligible. The meat and vegetable ration was in the majority of cases equally satisfactory, but in certain consignments the crates in which the tins were packed were not sufficiently strong to withstand the rough usage to which they were subjected in transport and as a result the tins were damaged. In such cases the contents did not become putrid in the ordinary sense of the word but underwent a peculiar form of fermentation, as a result of which the contents acquired a sour taste and smell and much gas was evolved.

The meat ration was highly appreciated by the troops, and the occasions on which mutton was issued were welcomed as a change from the monotony of beef. The meat and vegetable ration was palatable, but men soon tired of it when it appeared too frequently, and in the opinion of some it was too rich and sickly in flavour to form a staple article of diet. The pork and beans ration was preferred by most men, although its name is somewhat of a misnomer as the ration consisted chiefly of haricot beans with only a small addition of fat pork which blends with the beans during preparation and cannot be distinguished from them. It would have been preferable to have called this ration " baked beans." In some cases the full nutritive value of the pork and beans ration was not utilized as many men swallowed the beans without chewing them and they appeared unchanged in the fæces.

Bread, Biscuit and Flour.—The field ration as laid down in Allowance Regulations was reduced in respect of bread, biscuit, and flour in January 1917 to 1 lb. of bread or ¾ lb. of biscuit or flour, and in July of the same year the amount of biscuit was still further reduced to 10 oz. In the early part of 1917 a separate ration for troops on the lines of communication was introduced in which 14 oz. of bread or 8¾ oz. of biscuit were issued. The issue, however, in no case consisted entirely of bread but was divided in the proportion of 75 per cent. of bread and 25 per cent. of biscuit, so that the actual issue to troops in the field consisted normally of 12 oz. of bread and

2 oz. of biscuit, and to troops on the lines of communication 10·5 oz. of bread and 2·19 oz. of biscuit. In practice, however, it frequently happened that the former received considerably less than 75 per cent. of the issue in bread.

The reduction in the bread ration was compensated for by the introduction into the ration of oatmeal and rice.

These emendations were embodied in the ration pamphlet first issued. In the revised ration pamphlet the absolute amounts of bread and biscuit were stated separately.

The quality of the bread was almost invariably excellent. At one period considerable trouble with regard to "ropiness" was experienced at the bakeries but this was eventually overcome. Bread issued in army areas was somewhat stale since in most cases several days elapsed between baking and issue owing to time taken in transit. The bakeries were at the bases and if it had been possible to erect bakeries in army areas much of the criticism in regard to staleness of bread would have been obviated. Biscuits showed a continuous improvement in palatability during the progress of the war, but they never became a popular article of diet; an occasional biscuit was generally appreciated but a daily issue became monotonous and, in spite of ingenious cooking recipes by which it was hoped that biscuits would be economically utilized, considerable waste occurred. In many cases units did not trouble to draw their full issue of biscuits and to this extent were deprived of the full energy supply arranged for in the ration, or if biscuits were fully drawn they were not consumed. Attention was frequently drawn to these points by the D.G.M.S. who recommended that on the lines of communication the bread ration should consist entirely of bread in place of bread and biscuits. There was apparently no administrative difficulty in arranging for such an issue, but on military grounds it was decided that a large reserve of biscuits was necessary in view of a possible advance and that such reserve had to be turned over within a specified time, the only way in which this could be done being by a general issue of biscuits to all troops.

Bacon.—Bacon was a much appreciated element of the ration and on the whole was of good quality. During a short period trouble was experienced with the development of "slime" in borax packed bacon, but with greater attention and care in transit and storage this was overcome. Latterly, much of the bacon was coarse in character and very fat, but in spite of this was a greatly relished part of the ration.

In the earlier stages of the war the ration consisted of 4 oz. for troops in the field and 3 oz. for troops on the lines of communication. This was the allowance noted in the first ration pamphlet. Later on it became necessary to reduce the amount to 3 oz. for all troops in the revised ration pamphlet.

Cheese.—Cheese was a popular element of the ration, but the amount originally issued (3 oz.) was found to be excessive and some waste occurred. A reduction to 2 oz. was effected, and later on this was reduced to 1 oz. for troops on the lines of communication both in the first and revised ration pamphlets. This amount was found ample in all cases.

Butter and Margarine.—Butter was issued as an extra until 1917, when 2 oz. were issued as a definite ration thrice weekly to troops in the field. At the same time 1 oz. of margarine was issued to troops on the lines of communication. Later on 1 oz. of butter or margarine, according to whichever was available, was issued to all troops.

Fresh Vegetables.—In 1914 the importance of fresh vegetables from an antiscorbutic point of view was just beginning to be established on irrefutable scientific grounds and early in the campaign the D.G.M.S. insisted on the uselessness of dried vegetables as a substitute for fresh vegetables. The supply of fresh vegetables was, however, one of the greatest rationing difficulties which had to be contended with and notwithstanding repeated and urgent representations on the importance of an adequate supply, fresh vegetables were too often insufficient in amount or not forthcoming, especially in the winter-time. Although the ration pamphlet provided for 8 oz. of fresh vegetables, in which potatoes and onions were included, on many occasions nothing like that amount was available for issue. During the winter the D.G.M.S. agreed to the suggestion of the issue of an orange per man daily and it was possible when vegetables were short to make this issue. It proved very popular and was undoubtedly conducive to the health of the troops. It would appear from enquiries which were made that units receiving an ample supply of vegetables showed a smaller incidence of those affections classified as "inflammation of connective tissue" than did those in which the supply of vegetables was inadequate, although systematic and controlled investigation into this point was impracticable under war conditions.

The following table summarizes the various changes which were made in the field service ration on the Western front during the war.

TABLE I.

Statement showing Scale of Rations issuable to British and Dominion Troops in France, and giving Reductions effected during the whole Period of the War, and up to 30th September, 1918. *Daily Scale unless otherwise stated.*

Article.	Field Ration (Full Scale) for Fighting Troops at Front.								Rations for Troops on L. of C.*			
	First Scale drawn up.	Scale from 29.10.15	Scale from 4.4.16.	Scale from 20.1.17.	Scale from about 1.7.17.	Scale from 26.1.18.	Scale from 23.9.18	Total Reduction per Man per Day.	Scale from 17.4.17 (First Scale).	Scale from about 1.7.17.	Scale from 23.9.18 to 31.12.18	Total Reduction per Man per Day.
							Oz.				Oz.	
Meat (fresh or frozen) or Meat (preserved) ..	1¼ lb. or 1 lb. (nom.)	1 lb. or ¾ lb. (nom.)	1 lb. or ¾ lb. (nom.)	1 lb. or ¾ lb. (nom.)	1 lb. or 9 oz.	1 lb. or 9 oz.	15	5 oz. (approx.	12 oz. or —	12 oz. or 6¾ oz.	9⅔	2⅓ oz.
Bread † or Biscuit or flour ..	1¼ lb. or ¾ lb.	1¼ lb. or ¾ lb.	1¼ lb. or ¾ lb.	1 lb. or ¾ lb.	1 lb. or 10 oz.	1 lb. or 10 oz.	16¼	3¾ oz. (nearly)	14 oz. or —	14 oz. or 8¾ oz.	14¼	¼ oz. increase
Bacon	4 oz.	4 oz.	4 oz.	4 oz.	4 oz.	4 oz.	3	1 oz.	3 oz.	3 oz.	3	—
Cheese	3 oz.	3 oz.	3 oz.	2 oz.	2 oz.	2 oz.	2	1 oz.	2 oz.	2 oz.	1	1 oz.
Fresh vegetables .. or	8 oz.	8 oz.	8 oz.	8 oz.	8 oz.	8 oz.	8	—	8 oz.	8 oz.	8	—
Dried vegetables ..	2 oz.	2 oz.	2 oz.	2 oz.	2 oz.	2 oz.	2	—	2 oz.	2 oz.	2	—
Tea	⅝ oz.	⅝ oz.	⅝ oz.	⅝ oz.	⅝ oz.	½ oz.	½	⅛ oz.	½ oz.	½ oz.	⅜	⅛ oz.

Jam	4 oz.	4 oz.	3 oz.	3 oz.	3 oz.	3 oz.	3	1 oz.	3 oz.	3 oz.	3	---
Butter	Issued in the form of an "extra" until about 1.7.17.				2 oz. (thrice weekly).	2 oz.	1	1/7 oz. increase	—	—	—	—
Margarine	—	—	—	—	—	—	—	—	1 oz.	1 oz.	1	—
Sugar	3 oz.	3 oz.	3 oz.	3 oz.	3 oz.	3 oz.	2½	½ oz.	2 oz.	2 oz.	1	1 oz.
Oatmeal (thrice weekly)	Issued in the form of an "extra" until about 1.7.17.				2 oz.	2 oz.	1	1/7 oz. increase	—	—	1	1 oz. increase
Rice	do.		do.		1 oz.	1 oz.	1	—	2 oz.	2 oz.	2	—
Salt	½ oz.	½ oz.	½ oz.	½ oz.	¼ oz.	¼ oz.	¼	¼ oz.	¼ oz.	¼ oz.	¼	—
Mustard	1/20 oz.	1/50 oz.	1/50 oz.	1/50 oz.	1/100 oz.	1/100 oz.	1/100	1/25 oz.	1/50 oz.	1/100 oz.	1/100	1/100 oz.
Pepper	1/36 oz.	1/36 oz.	1/36 oz.	1/36 oz.	1/100 oz.	1/100 oz.	1/100	4/225 oz.	1/36 oz.	1/100 oz.	1/100	4/225 oz.
Milk (condensed) ..	1/16 tin	1/16 tin	1/12 tin	1 oz.	1 oz.	1 oz.	1	Slight increase of about ½ oz.	1 oz.	1 oz.	1	—
Pickles (weekly) ..	1 oz.	1 oz.	1 oz.	1 oz.	1 oz.	1 oz.	3/7 (daily)	3/7 oz.	1 oz.	1 oz.	3/7 (daily)	3/7 oz. increase
Energy value in calories	4,595	4,276	4,232	3,851	4,185	4,185	4,111		3,559	3,559	3,313	

* L. of C. Scale was abolished in January 1919. It was then decided that all troops should receive the one general scale of rations, *i.e.*, full "field service" scale.

† Bread and flour issuable daily; figures are calculated on the basis that 10 oz. flour = 16 oz. bread. (Scales from 23.9.18.)

Great variation in the rations had to be considered in order to meet the requirements of the Indian contingents and the different races employed in labour companies.

The essentials of the field ration for Indian personnel, as finally revised, were as follows :—

Atta	20 oz.
Fresh meat	4 ,,
Dhall	2 ,,
Dried vegetables	2 ,,
Or fresh vegetables	8 ,,
Ghi	1¼ ,,
Nut oil	1 ,,
Sugar	2 ,,
Sugar (when sweetened condensed milk is issued)	1¼ ,,
Tea	¼ ,,
Mixed spices, composed of ginger, turmeric, chillies and garlic	¼ ,,
Condensed milk	1 ,,
Jam (once a week)	2 ,,
Salt	½ ,,
Pickles (once a week)	¼ ,,

Men when in the trenches received an extra issue of 2 oz. of condensed milk.

The iron ration issued to Indian troops consisted of: Biscuit 1½ lb., gur 8 oz., tea 1 oz., and condensed milk 6 oz. or dried milk 2½ oz. in lieu, when available. When travelling by train the troops received: Biscuit 1¼ lb., dried fruits 2 oz., tea ⅓ oz., gur 3 oz., ghi 3 oz.

The special ration scales drawn up for Chinese, Egyptian, Fijian, Naga Hill, and Kaffir personnel were as follows :—

Chinese Labour Corps.

Meat (frozen or fresh)	10 oz.
Rice	8 ,,
Bread	10 ,,
Flour	10 ,,
Fresh vegetables	8 ,,
Sugar	1 ,,
Bacon	2 ,,
Nut oil (fluid)	¼ ,,
Margarine	1 ,,
Cheese	1 ,,
Tea	¼ ,,
Salt	½ ,,

The calorie value of this ration was 4,213. In March 1918, owing to shortage of supplies, the meat was reduced to 4 oz. and the bread and flour to 8 oz., the rice was increased to 10 oz., and the nut oil to 1½ oz. The train ration for Chinese labourers consisted of: preserved meat 5 oz., biscuit 1¼ lb., dried fruits 2 oz., sugar 1 oz., margarine 1 oz., cheese 1 oz., tea ½ oz.

Egyptian Labour Corps.

Fresh or frozen meat	½ lb.
Bread	32 oz.
Cheese	3 ,,
Jam	2 ,,
Fresh vegetables	8 ,,
Tea	⅜ ,,
Sugar	1½ ,,
Salt	½ ,,
Semu or ghi or margarine	2 ,,
Lentils or saidi beans	4 ,,
Garlic (twice weekly)	¼ ,,

The calorie value of this ration was 4,291.

Fijian Labourers.

Frozen meat	8 oz.
Bread	24 ,,
Rice	8 ,,
Sugar	1½ ,,
Fresh vegetables	8 ,,
Margarine	2 ,,
Jam	2 ,,
Milk	1 ,,
Salt	¼ ,,
Tea	¼ ,,

The calorie value of this ration was 3,859.

Naga Hill Labourers.

Rice	2 lb.
Meat (fresh or frozen)	8 oz.
Dried vegetables	2 ,,
Or fresh vegetables	8 ,,
Chillies	¼ ,,
Milk	1 ,,
Jam (once a week)	4 ,,
Salt	½ ,,
Sugar	1¼ ,,
Or sugar (when sweetened condensed milk is issued)	1 ,,
Tea	¼ ,,
Pickles (once a week)	1 ,,

South African Native Labour Corps.

Frozen meat	1 lb.
Or preserved meat	9 oz.
Mealie meal	1 lb.
Bread	1 ,,
Coffee	1 oz.
Sugar	2 ,,
Fresh vegetables	8 ,,

The calorie value of this ration was 4,445.

Special Rations for Forestry and Labour Companies.

Troops engaged in arduous labour, such as railway construction, forestry and so on, could draw supplementary rations in accordance with scales laid down in the ration pamphlet.

The employment of Canadian personnel in forestry work necessitated the issue of a special ration. The work was arduous and prolonged and the men were of fine physique. After correspondence with the War Office the following ration was approved :—

Meat	16	oz.
Pork and beans	8	,,
Bread	20	,,
Or flour	16	,,
Yeast	·0027	oz.
Hops	·0003	oz.
Beans, peas or rice	1	oz.
Oatmeal	2	,,
Bacon	4	,,
Butter or margarine	3	,,
Cheese	2	,,
Fresh vegetables	12	,,
Jam	3	,,
Tea	$\frac{3}{4}$	,,
Sugar	3	,,
Condensed milk (unsweetened)	1	,,
Salt	$\frac{1}{4}$	,,
Pepper	$\frac{1}{100}$	,,
Mustard	$\frac{1}{100}$	,,
Pickles (thrice weekly)	1	,,

This ration was calculated to be equivalent to 5,681 calories. In France a ration with a still higher calorie value was issued.

For British forestry units the following ration, equivalent to 4,852 calories, was issued :—

Meat, fresh or frozen	$9\frac{3}{5}$	oz.
Meat, preserved	$3\frac{3}{5}$	,,
Pork and beans (four days a week)	$\frac{3}{10}$	tin.
Meat and vegetable ration (three days a week)	$\frac{1}{5}$	,,
Bread	$14\frac{2}{5}$	oz.
Flour	$3\frac{1}{5}$	,,
Rice, peas or beans	$1\frac{1}{5}$	,,
Oatmeal	$1\frac{1}{5}$	,,
Bacon	$3\frac{3}{5}$	,,
Butter or margarine	$1\frac{1}{5}$	,,
Cheese	$2\frac{2}{5}$	,,
Fresh vegetables	$9\frac{3}{5}$	,,
Jam	$3\frac{3}{5}$	,,
Tea	$\frac{1}{2}$	,,
Sugar	3	,,
Milk, condensed	$1\frac{1}{5}$	,,
Pickles (thrice weekly)	1	,,
Salt	$\frac{1}{4}$	,,
Pepper	$\frac{1}{100}$	,,
Mustard	$\frac{1}{100}$	,,

Supply of Food in the Trenches.

The importance of supplying troops in the trenches not only with the complete daily field ration but also with certain comforts was early recognized as an important factor both in maintaining resistance to disease and adding to the general welfare. The harmful effects of exposure and the resulting occurrence of trench foot were to some extent counteracted by the liberal ration and the means adopted for ensuring a daily supply of hot food.

In addition to the $\frac{5}{8}$ oz. of tea in the field service ration the men in the trenches received an extra $\frac{1}{2}$ oz. of tea and $\frac{3}{4}$ oz. of sugar. This increase served a double purpose, in that not only was extra stimulant available, but it necessitated the water used being boiled when made into tea. Hot cocoa or soup was also distributed in the trenches as far as possible between the hours of 2 and 4 a.m. and special soup kitchens for brigades were organized near the gum-boot stores, at which men were given a cup of hot soup when proceeding to and returning from the trenches. In some reserve trenches hot soup was available at depôts of the Y.M.C.A.

An issue of rum was authorized only at the discretion of the general officer commanding, on the recommendation of the medical officer, and was made concurrently with the issue of pea-soup or meat extract cubes, but was not issued to total abstainers or men who did not desire it.

In the earlier months of the war the only means of heating food in the trenches was on braziers, which were neither satisfactory nor sufficient. Later, the provision of "solidified alcohol" in a tin container in the form of a small stove was generally appreciated for preparing hot drink, and for the further heating of stew in mess-tins by the individual soldier.

In order to make certain that the men in the trenches were supplied with hot food, it was necessary to devise some means by which the rations cooked behind the line were kept hot during their conveyance to the trenches. This was done by means of food carriers, jacketed and provided with handles; they were either of an official pattern in metal or improvised from biscuit boxes. In the latter case, the non-conducting material was hay, held in place by coarse canvas nailed to the inner walls of the box, which was of a size to contain one Flanders camp kettle. This improvised form kept food hot up to eighteen hours. For carrying liquid food, two-gallon petrol tins were utilized. These were made to retain their heat by a covering of felt and

waterproof sheeting sewn together, the waterproof sheeting being outside. Enough material was used to form overlaps, so that the tin was completely covered. These carriers were hung on braces, which passed over a man's shoulders, thus allowing one man to carry two, one in front and the other behind. They retained heat sufficiently well for the space of six hours. In all patterns of carriers employed it was found to be essential that the insulated covers should be kept dry, as otherwise loss of heat resulted.

The method of distribution in these carriers was as follows: The hot food was placed in petrol tins at the quartermaster's stores. The tins were then placed in the hot compartment of the front limber of a travelling cooker and taken up with the rations to the ration dump. At the ration dump the tins were taken from the cooker and placed immediately into the carriers which were brought down from the trenches by the ration party each morning.

RATIONS IN THE EGYPTIAN EXPEDITIONARY FORCE.

Rations for British troops were issued according to the following scale :—

Fresh meat	$\frac{3}{4}$ lb.
Or preserved meat	9 oz.
Bread	1 lb.
Or biscuit or flour	$\frac{3}{4}$,,
Condensed milk	$1\frac{1}{3}$ oz.
Bacon	3 ,,
(4 oz. to troops on the Palestine front).	
Fresh vegetables or onions	8 ,,
Or dried vegetables, dried peas, lentils, &c.	4 ,,
Potatoes	4 ,,
Tea	$\frac{5}{8}$,,
Sugar	3 ,,
Cheese	3 ,,
Salt	$\frac{1}{4}$,,
Pepper	$\frac{1}{100}$,,
Mustard	$\frac{1}{100}$,,

A ration of lime juice 1 oz. with sugar $\frac{1}{2}$ oz. was issued whenever fresh vegetables could not be obtained. When available the following extra issues were made :—

Mondays and Fridays	2 oz. of rice and 2 oz. of dried fruits.
Tuesdays and Thursdays	2 oz. of oatmeal.
Wednesdays and Saturdays	2 oz. of flour, 2 oz. of dried fruits.
Sundays	2 oz. of rice and $\frac{1}{4}$ oz. of curry powder in lieu of the mustard issue.

In the summer months jam was given and cheese was not issued. The calorie value of the winter scale was estimated to

be about 4,100. On the whole the ration was satisfactory, but dried vegetables could not effectively replace fresh vegetables, and when this supply was insufficient, an increase in the issue of potatoes was recommended, 8 oz. of potatoes and 4 oz. of fresh vegetables being considered the best issue.

An issue of 4 oz. of bacon was made to army corps and army troops on the Palestine front. Men of the British West India Regiments drew the same scale of rations as British troops. When available fresh or cured fish was given in place of bacon, and cheese was not usually issued during the summer months.

A special ration was given to British troops of the mobile column for the winter months of 1917–18. It was as follows :—

Preserved meat (1 lb. nominal)	12	oz.
Biscuit	12	,,
Condensed milk	1	,,
Jam	4	,,
Sugar	3	,,
Tea	⅝	,,
Cheese	3	,,
Dried fruits	6	,,
Soup squares	2	,,
Cocoa	1	,,

The calorie value of this ration was about 3,900. This ration was used when transport had to be cut down to the minimum. It contained no vegetables and the food was almost entirely devitalized. The ration could only be given for short periods without detriment to health, unless fresh vegetables could be obtained locally.

Indian troops on the normal scale received the following ration :—

Atta	1½	lb.
Fresh meat	4	oz.
Dhall	4	,,
Fresh vegetables or onions, including 2 oz. of potatoes ..	8	,,
Or dried vegetables	2	,,
Ghi	2	,,
Tea	½	,,
Gur or sugar	2	,,
Chillies	⅙	,,
Garlic	⅙	,,
Turmeric	⅙	,,
Ginger	⅓	,,
Condensed milk	1	,,
Salt	½	,,
Jam (once a week)	4	,,

Non-meat eaters received 2 oz. of gur or sugar or 3 oz. of milk in place of the 4 oz. of meat.

On the mobile scale Indian troops received :—

Biscuit	1¼ lb.
Jam	4 oz.
Sugar	3 ,,
Condensed milk	1½ ,,
Dried fruits (dates if possible)	6 ,,
Tea	⅝ ,,
Salt	¼ ,,

The normal scale ration was satisfactory, but the mobile scale had the same defects as that issued to British troops; it was almost entirely devitalized and did not contain any vegetables. It also contained very little fat; this was remedied subsequently by the issue of 2½ oz. of ghi.

Egyptian troops had a ration very similar to that issued to Indian troops, in that the protein was mainly of vegetable value, but the fats were low, the issue of vegetables was small and there was no sugar. The ration was as follows :—

Bread	1 lb. 11¾ oz.
Lentils	4½ ,,
Rice	2¼ ,,
Butter	⅔ ,,
Meat	4 ,,
Salt	½ ,,
Fresh vegetables	5 ,,
Onions	⅝ ,,

Troops of the Arab legion received 24 oz. of native bread, fat as cotton-seed oil, 1 oz., sugar ½ oz., meat 4 oz., fresh vegetables 4 oz., and lentils or rice 3½ oz.

On the whole the supply of fresh food was satisfactory. Vegetables were obtained by local contract from the Nile Delta and frozen meat was supplied from Australia, special arrangements for its reception being made at Port Said. A difficulty was experienced in connection with the supposed blowing of the large 7 lb. tin of preserved meat. Large quantities were destroyed at one time as the tins appeared to be blown, but an examination in London revealed nothing of a noxious character, and the blowing was apparently due to the expansion of small quantities of sterilized air caused by the extreme heat in the summer months.

On the arrival of West African troops a ration suitable to their needs had to be issued. It was as follows :—

Rice	1½ lb.
Fresh meat	8 oz.
Sugar	2 ,,
Coffee, tea or cocoa	½ ,,
Potatoes	8 ,,
Fresh vegetables	4 ,,
Biscuit or mealie meal	4 ,,
Chillies	½ ,,
Salt	1 ,,
Palm oil	2 ,,

Rations for prisoners of war were issued according to the following scales :—

German, Austrian and Bulgarian Prisoners of War.

Bread	9 oz.
Broken biscuit	4 ,,
Meat (five days a week)	6 ,,
Salt-cured herrings (two days a week)	10 ,,
Tea	⅛ ,,
Or coffee	⅜ ,,
Sugar	1 ,,
Salt	½ ,,
Potatoes	4 ,,
Other fresh vegetables	4 ,,
Split peas or beans	2 ,,
Jam	1 ,,
Margarine	1 ,,
Cheese	2 ,,
Maize meal	1½ ,,
Rice	3 ,,
Oatmeal	2 ,,

When prisoners were not employed on work deductions were made unless a medical officer advised to the contrary in any particular case.

Turkish Prisoners of War.

Quantity in dirhems* unless otherwise stated.

	Monday.	*Tuesday.*	*Wednesday.*	*Thursday.*	*Friday.*	*Saturday.*	*Sunday.*
Bread ..	250	250	250	250	250	250	250
Meat ..	—	23½	—	23½	—	—	23½
Vegetables	45	45	45	45	45	45	45
Rice ..	30	30	30	30	30	30	30
Oil ..	5	5	5	5	5	5	5
Pepper ..	—	½	—	½	—	—	½
Salt ..	5	5	5	5	5	5	5
Onions ..	5	5	5	5	5	5	5
Tea ..	½ oz.	½ oz.	½ oz.	½ oz.	½ oz.	½ oz.	½ oz.
Sugar ..	¾ oz.	¾ oz.	¾ oz.	¾ oz.	¾ oz.	¾ oz.	¾ oz.
Cheese ..	—	20	—	20	—	20	—
Olives ..	15	—	15	—	15	—	15
Lentils or beans.	35	—	35	—	35	35	—

* One dirhem equals 3·12 grm.

The prisoners of war rations are interesting in view of the outbreak of pellagra among Turkish prisoners. This was investigated by a committee of enquiry, for which Professor W. H. Wilson prepared a table (Table II) showing the

TABLE II.

Percentage Composition and Food Value of various Food-stuffs.

Food Material.	A. Gross Protein. Per cent.	B. Available Protein. Per cent.	C. Biological Value of Protein.	D. Fat available. Per cent.	E. Carbo-hydrate available. Per cent.	F. Mineral Matter (Salts).	G. Calories per 100 Grammes.	H. Calories per Ounce.	I. Amount in Grammes to yield 100 Calories.
Native bread (wheaten) ..	6·7	5·0	2·0	1·0	47·5	1·2	225	64·0	44·5
Native bread (millet) ..	6·4	3·4	1·36	1·5	45·0	1·2	212	61·0	47·0
European bread (medium)	7·5	6·0	2·4	·7	50·0	1·0	236	67·0	42·5
Biscuit	10·7	9·4	3·8	8·0	68·0	1·0	394	112·0	25·5
Meat, beef (bone) ..	20·0	19·0	19·0	5·0	—	1·3	125	36·0	80·0
„ mutton „ ..	18·0	17·1	17·1	6·0	—	1·9	127	36·5	79·5
„ veal „ ..	20·0	19·0	19·0	6·0	—	1·3	134	38·0	74·0
Bacon	10·5	10·0	10·0	60·0	—	4·5	600	172·0	16·7
Rabbit (edible part) ..	21·4	20·3	20·3	5·0	—	1·0	134	38·0	74·0
Chicken „ „ ..	21·0	20·0	20·0	6·0	—	1·0	140	40·0	71·5
Pigeon „ „ ..	22·0	20·8	20·8	1·0	—	1·0	97	28·0	103·0
Tripe	11·7	11·0	11·0	1·2	—	1·0	57	19·0	176·0
Liver	20·4	20·0	20·0	4·0	1·7	1·0	128	36·5	79·5
Fish (plus bone)	16·5	16·0	16·0	4·0	—	1·0	104	29·5	96·0
Salt herrings (minus 33 per cent. refuse).	21·0	20·0	20·0	11·0	—	11·0	186	53·0	54·0
Fats.									
Suet	4·7	4·5	4·5	80·0	—	·3	762	217·0	13·1
Fresh butter	1·0	1·0	1·0	85·0	·5	3·0	795	226·0	12·6
Lemma (melted butter) ..	—	—	—	93·0	—	4·0	865	246·0	11·5
†Vegetable butter oil ..	—	—	—	100·0	—	—	930	263·0	10·7

Dairy Products, etc.									
Eggs (1=40 grm.)	13·0	12·5	12·5	10·5	—	1·2	150	42·5	66·5
Cow's milk	3·5	3·4	3·4	4·0	5·0	·7	72	21·5	138·0
Camoose (buffalo) milk ..	4·16	4·0	4·0	7·9	4·8	·8	109	31·0	92·0
Condensed milk (unsweetened)	9·6	9·1	9·1	9·3	11·2	1·7	170	48·0	59·0
Dried milk	24·5	23·5	23·5	26·5	36·0	6·1	492	140·0	203·0
Cheese (Dutch)	27·0	25·3	25·3	25·0	—	6·0	340	97·0	29·5
Native cheese (good quality)	12·6	12·0	12·0	16·0	—	—	199	56·5	50·5
Native cheese (skim-milk)	22·0	21·0	21·0	1·2	—	9 to 15	99	28·2	101·0
Native cheese (Maltese) ..	12·8	12·3	12·3	12·7	—	—	170	48·0	59·0
Pulse.									
Beans (horse)	26·6	18·6	10·3	2·0	54·0	3·3	317	90·0	33·0
Lentils	27·5	19·3	10·7	2·0	59·8	2·7	324	92·0	32·0
Lupins	Approximately as scarce as peas.								
Lubia									
Ground nut (arachis) ..	26·0	19·0	10·3*	43·0	16·0	1·3	562	160·0	17·8
Ful Sudanis									
Soya bean meal (fat extracted)	40·0	32·0	17·8	2·1	28·5	—	269	76·0	37·0
Peas	21·0	14·3	8·6	1·8	55·0	2·6	304	86·0	33·0
Farinaceous Food.									
Rice or ground rice ..	7·7	6·5	6·0	·4	76·0	·4	330	94·0	30·5
Wheat flour	12·0	9·6	3·8	1·7	67·5	1·2	326	93·0	30·7
Barley ,, ...	10·0	8·0	3·2	2·2	69·0	2·4	341	97·0	29·3
Millet ,, ...	8·2	6·6	2·0	4·2	68·0	1·7	344	98·0	29·0
Maize ,, ...	8·4	6·7	2·0	4·7	72·0	1·3	357	101·0	28·2
Oatmeal	15·0	12·0	4·8*	7·0	64·0	2·0	378	108·0	26·5
Macaroni	11·0	9·8	3·9	·5	74·0	·6	349	99·0	28·5
Vermicelli	12·0	9·6	3·8	·5	74·0	·7	348	99·0	28·5
Semolina	12·0	9·6	3·8	·7	75·0	·7	354	100·0	28·4

NOTE.—Values marked * in column C are assumed values, those not so marked are known.

† Vegetable butter, Egyptian army butter substitute, consists of 95 per cent. cotton-seed oil and 5 per cent. butter.

TABLE II.—*cont.*

Percentage Composition and Food Value of various Food-stuffs.

Food Material.	A. Gross Protein. Per cent.	B. Available Protein. Per cent.	C. Biological Value of Protein.	D. Fat available. Per cent.	E. Carbohydrate available. Per cent.	F. Mineral Matter (Salts).	G. Calories per 100 Grammes.	H. Calories per Ounce.	I. Amount in Grammes to yield 100 Calories.
Tapioca	—	—	—	·2	84·0	—	347	98·5	28·7
Cornflour	·5	·4	·2	—	82·0	·3	338	96·0	29·5
Sugar	—	—	—	—	100·0	—	410	117·0	24·5
Chocolate	7·8	6·0	3·0*	21·0	62·0	2·2	475	135·0	21·2
Cocoa (Epps)	6·7	6·0	3·0*	15·0	71·0	1·5	456	130·0	22·0
Native sweetmeat (Halwa)	1·3	1·0	·4	25·0	66·0	·5	506	142·0	19·8
Treacle (Assal)	?	—	—	—	69·0	3·0	282	80·0	35·1
Jam or marmalade ..	1·0	·8	·4*	·1	65·0	·3	270	76·0	37·0
Dried fruit, dates	2·1	1·9	·9*	2·5	75·0	1·5	339	96·5	29·5
,, ,, ,, (Agwa) ..	2·1	1·9	·9*	·6	47·0	1·3	206	58·5	48·5
,, ,, apricots ..	1·6	1·2	·6*	2·2	60·0	2·4	270	77·0	37·0
,, ,, figs	5·5	4·4	2·0*	·9	62·0	2·3	282	80·0	35·5
,, ,, raisins ..	2·5	2·0	1·0*	4·7	74·0	4·1	355	100·0	24·4
,, ,, prunes ..	2·4	2·0	1·0*	·8	66·0	1·5	286	81·5	35·0
Green Vegetables and Fruit.									
Potato (with skin 20 p.c.) ..	1·8	1·6	1·27	·1	15·0	1·0	70·6	20·8	142·0
Various green vegetables cooked (mean)	1·25	1·0	·5*	—	3·0	1·0	16·5	4·8	610·0
Tomatoes	1·2	·9	·4*	·2	4·0	·6	22·0	6·4	455·0
Turnips	·9	·7	·3*	·1	1·0	·3	8·0	2·4	1250·0
Carrots	·5	·4	·2*	·5	3·3	1·5	20·0	5·7	500·0
Onions and leeks	1·2	·9	·4*	1·8	5·0	·16	41·0	12·0	245·0
Cabbage	2·6	2·0	·1*	·2	6·0	1·6	35·0	10·3	282·0

Spinach	3·8	3·0	1·5*	·9	8·0	2·1	54·0	16·0	186·0
Vegetable marrow	·16	·12	·1*	·2	2·0	·8	10·5	3·1	960·0
Yams	2·2	1·8	1·6	·5	15·0	1·5	75·0	22·0	133·0
Sweet potatoes	1·6	1·3	1·1	·5	22·5	·7	101·0	28·7	99·0
Artichokes (tabers)	2·6	2·1	1·0*	·2	16·0	1·0	76·5	22·5	132·0
Beetroot	2·3	1·8	·9*	·1	7·2	1·6	37·0	10·9	270·0
Cucumbers	·8	·6	·3*	·2	3·0	·5	16·5	4·8	610·0
Egg plant (Aubergine Bedingan).	1·2	1·0	·5*	·3	5·0	·5	27·5	8·1	365·0
Lettuce	1·2	1·0	·5*	·3	2·7	·5	18·0	5·3	560·0
Radishes	1·3	1·0	·5*	·1	5·5	1·0	27·5	8·1	365·0
Olives (refuse 20 p.c.)	1·2	·8	·4*	20·0	5·0	4·4	210·0	62·0	48·0
Fresh Fruit, as purchased. (Refuse per cent.).									
Bananas .. 35	·8	·6	·3*	·42	14·2	·7	65·0	19·2	154·0
Oranges .. 28	·6	·45	·2*	·1	8·5	·4	38·0	11·8	265·0
Water-melons 60	·2	·15	·1*	·1	2·7	·2	13·0	3·8	770·0
Apples 25	·3	·2	·1*	·3	10·5	·3	44·0	13·0	226·0
Figs 10	1·4	1·1	·5*	—	17·0	·6	74·0	22·0	136·0
Grapes 25	1·0	·8	·4*	1·0	14·4	·5	71·0	21·0	145·0
Apricots 15	1·0	·8	·4*	·5	12·0	·4	61·0	18·0	164·0
Alcoholic Drinks.			Solid extract part nutritive.			*By wt. alcohol.*			
Light beer	—	—	5·4	—	—	3·7	48·0	14·0	209·0
Stout	—	—	8·0	—	—	5·2	69·0	20·2	145·0
Red wine (French claret)	—	—	2·4	—	—	8·2	67·0	20·0	149·0
Champagne (sweet)	—	—	12·0	—	—	9·5	119·0	35·0	84·0
Brandy	—	—	·02	—	—	45·0	314·0	92·5	32·0
Whisky	—	—	—	—	—	43·0	301·0	88·5	33·5
Rum	—	—	·13	—	—	43·5	306·0	90·0	33·0

NOTE.—Values marked * in Column C are assumed values, those not so marked are known.

percentage composition and food value of various food-stuffs. The details as to the percentage composition were taken from various works of reference and in some cases from analyses made in the laboratories of the Public Health Department or other laboratories in Egypt. Column A gives the gross protein and columns G, H and I the available (absorbable) nutritive components. The biological value of protein (column C) based chiefly on the observations of Thomas, gives the value of protein from various sources as compared with animal protein. Professor Wilson believed pellagra* to be associated ætiologically with an actual or relative deficiency in the biological protein value of the diets. He did not consider the figures in column C of much importance in an ordinary European diet in which food from animal sources forms a considerable part. In mainly vegetarian diets, such as are commonly met with in Eastern countries, however, the biological value of protein could not be neglected and for an adult man should not fall below 40 grm. daily. The figures for available value of protein in the table were based chiefly on the observations of Rubner and his co-workers. The table was constructed chiefly for use in Egypt and in regard to certain food-stuffs the figures are of importance. In first-class English beef and in meat from Australia, America, New Zealand, and the Argentine, the refuse, bone and non-edible parts is not more than 20 per cent., and the fat content is at least 20 per cent., while in Egyptian meat the refuse may be taken at 30 per cent. and the fat content 5 per cent. The quality of South African and Madagascar beef imported into Egypt did not appear to be very different from that of local origin.

Egyptian bread contains from 34 to 41 per cent. of water. The amount of protein in bread made from local flour is less than in that made from imported flour. The composition of wheat grown in Egypt varies greatly with the variety and conditions of soil and culture ; the total protein estimated from the total nitrogen of the grain may be as little as 8·5 per cent. and bread made from flour obtained from such wheat would be of very low protein content. Bread made from mixtures of wheat and dura (maize) flour contains less protein than pure wheaten bread.

Egyptian cheese is of the nature of curd cheese, sometimes made from whole milk, sometimes after skimming. It contains much water and salt.

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* See Diseases of the War, Vol. 1, Chapter XXI, p. 479.

The normal scale ration for European troops was estimated to contain 124·8 grm. of protein, biological value 92·6; fat 116·2 grm.; carbohydrate 492 grm.; calories 3,610.

The normal scale Indian ration contained 120·4 grm. protein, biological value 55·1; fat 96·1 grm.; carbohydrate 592 grm.; calories 3,810.

The non-labour scale for Turkish prisoners contained protein 90·5, biological value 37·2; fat 30·7; carbohydrate 492; calories 2,684. The labour diet was 102·4 protein, biological value 45·6; fat 33·3 grm.; carbohydrate 560 grm.; calories 3,026.

RATIONS OF THE MACEDONIAN EXPEDITIONARY FORCE.

British troops received the following ration daily:—

Fresh meat	1	lb.
Bread	1	,,
Or Biscuit	¾	,,
Or Flour	¾	,,
Bacon	4	oz.
Milk	1	,,
Jam (six days a week)	3	,,
Butter (one day a week when available)	2	,,
Fresh vegetables (including potatoes)	8	,,
Tea	⅝	,,
Or Coffee	½	,,
Or Cocoa	1	,,
Cheese (when available)	3	,,
Sugar	2½	,,

Supplementary issues:—

Sundays	Flour 2 oz., dried fruit 2 oz.
Wednesdays	,, ,, ,, ,,
Mondays	Rice 2 oz.
Thursdays	,, ,,
Saturdays	,, ,,
Tuesdays	Oatmeal 2 oz.
Fridays	,, ,,

The daily ration was estimated to contain:—

Protein.	*Fat.*	*Carbohydrate.*	*Calories.*
145 grm.	196 grm.	439 grm.	4,121

and the supplementary issues daily:—

Protein.	*Fat.*	*Carbohydrate.*	*Calories.*
6·7 grm.	1·7 grm.	53 grm.	263

For troops at the base and in lines of communication areas only ¾ lb. of meat was issued, except in the case of troops engaged on hard physical labour when the full ration was issued on the authority of the base commandant.

For men in the trenches and personnel of batteries in action and also for lorry drivers, ambulance car drivers and artificers, and personnel employed on night duty, 2 oz. of pea-soup or

1 oz. of cocoa and ½ oz. of sugar were given three times a week or daily during severe weather on the authority of general headquarters.

The ration was satisfactory but contained a large quantity of fat for the summer months. The D.M.S. of the force objected to dried vegetables being considered an equivalent of fresh vegetables and insisted that every effort should be made to supply fresh vegetables daily.

Indian personnel received the following ration :—

Atta	1½ lb.	Ginger	⅙ oz.
Fresh meat ..	4 oz.	Milk	1½ „
Dhall	2 „	Chillies	⅙ „
Ghi	3 „	Turmeric	⅙ „
Gur	3 „	Garlic	⅙ „
Potatoes	2 „	Dried fruits ..	2 „
Tea	⅓ „		

In place of dried fruits 6 oz. of green vegetables or onions might be issued.

In March 1918 the ration for British troops was modified ; the meat issue was reduced to 12 oz. daily, cheese was not given during the summer months, the fresh vegetables were increased to 12 oz., and jam was given daily. The other items remained much the same. In the supplementary issues dried fruit was given four days a week, the rice, oatmeal, and flour being unchanged. The result of these changes was to reduce the issue of fat to 170 grm. daily and the total calories to about 4,000.

In March 1918 a special ration for convalescent depôts was approved. It was similar to the ration just described, but the milk issue was increased and 4 oz. of rice, oatmeal or flour were given daily instead of the 2 oz. of the ordinary field ration.

Maltese personnel were employed in Salonika and these men were allowed the same scale as British troops, except that the meat was reduced to 8 oz. and the bread increased to 2 lb. ; no bacon was issued.

On 5th April, 1918, a special scale of rations for Macedonian labour corps was issued ; it was as follows :—

Bread	24 oz.
Fresh meat (four times a week)	4 „
Olives	1 „
Onions	4 „
Fresh vegetables or potatoes	4 „
Olive oil	1 „
Rice	4 „
Sugar	1 „
Beans or lentils	1 „
Dried fruit (three times a week)	2 „
Coffee	⅓ „

Rations for the Serbian army were issued according to the following scale :—

Bread (*pain biscuite*)	21⅛ oz.
Frozen meat	14 ,,
Rice, haricot beans, etc.	3⅛ ,,
Sugar	1 1/7 ,,
Coffee	6/7 ,,
Fats or lard (vegetaline)	1 1/14 ,,
Onions	5/7 ,,
Vinegar	5/7 ,,
Salt	5/7 ,,
Wine (twice a week)	9 ,,

The calorie value of the ration was estimated to be about 3,355.

RATIONS IN EAST AFRICA.

The ration question in German East Africa was one of great difficulty and complexity. Surgeon-General Pike and Lieut.-Colonel A. Balfour, who had been appointed by the War Office in 1917 to enquire into medical and sanitary matters in German East Africa, reported that the distance from sources of supply, the troubles of unloading and transhipment, the nature of the climate, the transport conditions, the rapidity of some of the military movements, without time for adequate administrative preparation, all played a part in accentuating the difficulties of a satisfactory system of supply. In addition, there was the problem of feeding not only the European, the Indian, and the African, but of catering for the peculiar dietaries of half-a-dozen African races; and now and again for imported labourers wholly unused to African food conditions.

The scale of rations for Europeans and for men of the West India Regiment in 1916 was as follows :—

Article.	Quantity.	Substitutes.
Meat, fresh or frozen.. ..	1 lb.	Preserved or salt meat, 1 lb.
Bread	1¼ ,,	Biscuits or flour, 1 lb., with ½ oz. ghi and baking powder.
Bacon	¼ ,,	Milk, 2 oz. and bacon, 2 oz.
Tea	⅝ oz.	—
Jam	¼ lb.	—
Sugar*	3 oz.	—
Salt	½ ,,	—
Pepper	1/36 ,,	—
Mustard	1/50 ,,	—
Fresh vegetables	½ lb.	Dried vegetables, 2 oz.

* 4 oz. sugar for all European troops beyond railhead.

When fresh vegetables were not obtainable 1 oz. of lime juice with $\frac{1}{3}$ oz. of sugar was allowed for each man daily. An issue of 2 oz. of milk and 2 oz. of cheese was authorized for all motor transport personnel working forward of Mtandawala. General officers in command of divisions were also empowered to issue $\frac{1}{64}$ gallon of rum daily on medical recommendation. Members of the nursing services received an extra issue of 8 oz. of condensed milk daily. An issue of 1 oz. of cocoa and 2 oz. of milk daily was given to motor transport drivers employed in driving cars or lorries on the lines of communication.

Indian troops and followers received the following ration :—

Atta	$1\frac{1}{2}$ lb.
Fresh meat	4 oz.
Dhall	4 ,,
Ghi	2 ,,
Gur	1 ,,
Fresh vegetables	6 ,,
Tea	$\frac{1}{3}$,,
Ginger	$\frac{1}{3}$,,
Chillies	$\frac{1}{6}$,,
Turmeric	$\frac{1}{6}$,,
Garlic	$\frac{1}{6}$,,
Salt	$\frac{1}{2}$,,
Milk	2 ,,

The following extras when required could be issued on the authority of division commanders :—

Atta	$\frac{1}{2}$ lb.
Ghi	1 oz.
Gur	2 ,,
Rum (25 per cent. U.P.) .. .. (fluid)	2 ,,
Lime juice and sugar, or gur	$\frac{1}{2}$,,

Indian mounted units when on patrol duty received :—

Fresh meat for making biltong	$1\frac{1}{4}$ lb.
Coarse flour biscuits	1 ,,
Atta	1 ,,
Tea	$\frac{1}{2}$ oz.
Sugar	4 ,,
Condensed milk	$\frac{4}{6}$,,
Dried vegetables	2 ,,

The following ordinary substitutes were sanctioned :—

1 lb. of rice for 1 lb. of atta.
3 oz. of gur for 1 lb. of meat.
2 lb. of fresh vegetables or 1 lb. of preserved fruit for 1 lb. of potatoes.

The atta in the Indian ration was more than sufficient, and experience in Mesopotamia with the same issue showed that chapatties made with atta were often found thrown away in

the incinerator. The substitution of rice for a portion of the atta was therefore advisable. The gur was not sufficient. The Indian is fond of sweet drinks, and 2 oz. of gur would have suited his requirements better. The gur could not be considered a satisfactory substitute for meat.

The scale of rations authorized for the Nigerian Brigade of the Gold Coast Regiment and all West African troops was :—

Rice	1 lb. 2 oz.
Biscuit or mealie meal	4 ,,
Fresh meat	8 ,,
Sugar	2 ,,
Chillies	¼ ,,
Cocoa, tea or coffee	⅓ ,,
Salt	1 ,,
Palm or cooking oil	2 ,,

This ration was deficient in vegetables. Attention was drawn to this defect and an issue was subsequently made.

The Arab company, gun-porters, and stretcher-bearers received daily :—

Rice	1 lb.
Meat or dates	½ ,,
Salt	½ oz.
Potatoes, bananas or onions	8 ,,
Mahindi flour	8 ,,
Ghi	2 ,,

This ration was not satisfactory ; it did not contain sugar, and dates could not be considered a satisfactory substitute for meat.

East African natives drew the following scale of rations :—

Fresh meat	8 oz.
Mealie meal	10 ,,
Rice	10 ,,
Beans	4 ,,
Gur	2 ,,
Ghi or cooking oil	2 ,,
Salt	½ ,,
Vegetables	6 ,,

The vegetable ration consisted of potatoes, onions, sweet potatoes, mohogo or bananas, or any one or all of these if available. When fresh meat was not available 2 oz. of beans, 1 oz. of ghi and 2 oz. of gur were issued per man daily. In the field, when troops were unable to cook, 8 oz. of preserved meat and 1 lb. of biscuits were issued instead of the above ration. Arabs received atta instead of mealie meal and also ⅓ oz. of tea and 1 oz. of sugar.

The scale of rations for carriers was as follows :—

British ranks and Goanese	As for British troops.
Indians	As for Indian troops.
Arabs, Swahili, and Somali clerks, headmen and interpreters	As for African troops.

The scale of rations issued to Cape Boys was :—

Mahindi meal	1½ lb.
Salt	½ oz.
Sugar	3 ,,
Meat	1 lb.
Tea	⅝ oz.
Or coffee	1 ,,
Potatoes	2 ,,
Or green vegetables in lieu if procurable.	

The vegetable ration was too small and there was no fat except that contained in the meat.

A voyage ration for West African troops and carriers proceeding from West to East Africa was provided, and consisted of :—

Bread or biscuit	8 oz.
Rice	8 ,,
Cocoa powder	½ ,,
Salt	½ ,,
Fresh vegetables	8 ,,
Meat, fresh or preserved	12 ,,
Sweet potatoes..	8 ,,
Sugar	½ ,,
Palm oil	1 ,,

In 1918 a scale of rations for Somalis was authorized as follows :—

Fresh meat	12 oz.
Rice	16 ,,
African ghi	2 ,,
Sugar	2 ,,
Coffee	2 ,,
Salt	½ ,,
Vegetables	2 ,,

The vegetables in this ration were insufficient.

The mere perusal of the rations issued in East Africa shows how complex was the problem of feeding troops and followers. The diet question was a physiological and economic problem, and it could not be expected that any supply department, however well versed in its own work, could unaided solve the problems with which it was confronted, and without scientific advice. If this had been the rule scales would not have been issued showing substitutes which physiologically were not substitutes at all. On reference to the War Office, defects

were pointed out and remedies suggested. Surgeon-General Pike and Lieut.-Colonel Balfour, after careful examination of all the facts, reported that there had been nothing like a general breakdown, and only those who knew the country could fully appreciate all that had been accomplished. At the same time, considering the scarcity of fresh vegetables and fruit, they thought more might have been accomplished in the way of starting gardens, and importing gardeners if necessary, as was done in the case of Mesopotamia. They were surprised, however, to find that, considering the defects in the rations, there had been so little scurvy and beri-beri. The explanation is probably that no troops were more than three months on very short rations, and care was taken as soon as the period of shortage was over to give a liberal dietary, especially to Indian troops, whose susceptibility to scurvy was well recognized.

RATIONS IN MESOPOTAMIA.

From the commencement of operations in November 1914 until 1916 the Mesopotamian Force was under the control of the Indian Government, and the field service scale of rations was that laid down in War Establishments, India. The field ration for British troops was :—

Bread	1 lb.
Potatoes	1 „
Salt	½ oz.
Fresh meat	1 lb.
Tea	1 oz.
Pepper	1/36 „
Bacon	3 „
Sugar	2½ „

The field ration for Indian troops and followers was :—

Atta	1½ lb.
Ghi	2 oz.
Tea	1/3 „
Turmeric	1/6 „
Fresh meat	4 „
Gur	1 „
Ginger	1/3 „
Garlic	1/6 „
Dhall	4 „
Potatoes	2 „
Chillies	1/6 „
Salt	½ „

As regards deficiency diseases, the British ration was on the whole satisfactory, but in respect of the vitamines which prevent beri-beri it depended on the supply of fresh meat, as the bread was made chiefly with white flour. The Indian ration was rich in these vitamines in consequence of the atta, a wheat flour containing the germ and some of the aleurone layer, and dhall, containing germ and coat of the lentils. It was, however, deficient in antiscorbutic vitamines, which were only present in the 2 oz. of potatoes and 4 oz. of fresh meat. Moreover, while British troops arrived in Mesopotamia well nourished, medical officers noted that Indian troops showed a considerable percentage of men anæmic, debilitated, and suffering from pyorrhœa. This condition of the Indian troops was attributed to the system of rationing then in vogue in India, where a cash allowance was made to each soldier, with which he bought his ration from the regimental bunniah ; there was consequently no guarantee that he bought and consumed even the limited field service ration. During 1914 and 1915 the river transport in Mesopotamia was taxed to its utmost in conveying troops and supplies and bringing sick and wounded downstream. No special provision was available for the transport of fresh fruit, vegetables, or fresh meat. The climatic conditions were such that fruit and vegetables sent by river from Basra generally arrived in a damaged condition and unfit for issue to the troops. It was not, therfore, surprising that scurvy constituted a great cause of wastage amongst Indian troops up to the end of 1916. Basra and Amara were centres of local production of fresh fruit and vegetables and the incidence of scurvy was very slight amongst the troops stationed there. There were no centres for the production of vegetables and fruit beyond Amara and the troops had to rely entirely on the river transport for the supply of these articles. There were no cases of scurvy amongst British troops, probably because of their better condition and the larger quantities of fresh meat and vegetables which they received. There were, however, some cases of beri-beri, such as never appeared amongst the Indian troops, who had plenty anti-beri-beri vitamines in the atta and dhall, in place of the white bread issued to the British troops.

The cause of the deficiency diseases in Mesopotamia was fully recognized by the D.M.S. of the Force and the consulting physician, Colonel W. H. Willcox, and steps were taken by them to put the ration scales on a scientific basis. Consequently on 4th July, 1916, the following revised scale of rations was authorized :—

British Troops. Field Rations.

Bread	1 lb.
Fresh meat	12 oz.
Bacon	3 ,,
Potatoes	1 lb.
Tea	1 oz.
Sugar	2½ ,,
Cheese	3 ,,
Rice	3 ,,
Jam	3 ,,
Condensed milk	2 ,,
Oatmeal	4 ,,
Salt	½ ,,
Pepper	1/36 ,,

Extras.

Chocolate	1 oz.
Bread	4 ,,
Lime juice	½ ,,
Sugar	½ ,,
Rum	4 ,,
Dates	4 ,,
Fresh fruit	4 ,,
Dry lentils	2 ,,
Curry powder	⅛ ,,
Limes (per man)	3

Indian Troops. Field Rations.

Atta	1½ lb.
Fresh meat	4 oz.
Dhall	4 ,,
Ghi	2 ,,
Gur	2 ,,
Potatoes	2 ,,
Fresh fruit	2 ,,
Condensed milk	2 ,,
Tea	⅓ ,,
Ginger	⅓ ,,
Chillies	⅙ ,,
Turmeric	⅙ ,,
Garlic	⅙ ,,
Salt	½ ,,

Extras.

Atta	½ lb.
Ghi	1 oz.
Or gur	2 ,,
Fresh meat	2 ,,
Fresh vegetables	4 ,,
Fresh fruit	4 ,,
Tamarind	2 ,,
Rum (25 per cent. under proof)	2 ,,

A further revision was made on 31st October, 1916, when the following rations were authorized :—

British Troops. Daily Issues.

Bread	1	lb.
Or biscuit when bread not available	12	oz.
Fresh meat	1	lb.
Or preserved meat when fresh not available	12	oz.
Pickles when preserved meat is issued	1	,,
Bacon	3	,,
Potatoes or fresh vegetables	12	,,
Or dried vegetables or fruit when fresh vegetables not available	3	,,
Tea	¾	,,
Cheese (not in summer)	3	,,
Sugar	3	,,
Jam or golden syrup	3	,,
Tinned milk	2	,,
Salt	½	,,
Fresh fruit	4	,,
Oxo (two cubes)	½	,,
Or pea soup (not in summer)	2	,,

Weekly Issues.

Biscuit (Thursday, in lieu of bread)	12	oz.
Preserved meat or meat and vegetable ration, or tinned rabbit, in lieu of fresh meat for troops beyond base	12	,,
Tinned vegetables	6	,,
Or dried vegetables (to be issued once a week in lieu of fresh vegetables)	3	,,
Sugar for stewing fruit	1	,,

Twice Weekly.

Marmite (not in summer)	¼	oz.

Thrice Weekly.

Oatmeal	3	oz.
Curry powder	⅛	,,
Tinned milk	1	,,
Butter (not in summer)	2	,,
Rice	2	,,
Lime juice (not in winter)	½	,,

Supply officers were ordered to keep a supply of rum during the winter season, for issue when sanctioned by divisional or higher commands. In lieu of rum, ½ oz. of tea and 1 oz. of sugar were issued to abstainers.

Indian Troops. Daily Issues.

Atta or rice	1 lb. 8 oz.
Fresh meat	6 ,,
Or dhall	2 ,,
And ghi (when fresh meat not available)	1 ,,
Milk (tinned)	2 ,,
Condiments	⅔ ,,
Tamarind	1 ,,
Gur (or sugar)	2 ,,
Ghi	2 ,,
Potatoes or fresh vegetables	6 ,,
Fresh fruit	4 ,,
Tea	⅓ ,,
Sugar	½ ,,
Salt	½ ,,

Weekly Issues.

Gur, or sugar for stewing fruit	1 oz.

Thrice Weekly.

Ghi or cooking oil	2 oz.
Lime juice	½ ,,

Supply officers were ordered to issue rum (or tea and sugar) as for British troops.

These rations were a considerable improvement and the Indian rations contained at least 14 oz. of foods having anti-scorbutic vitamines. The only difficulty was to convey the rations to the troops at the front; the fierce heat in summer rendered it impossible to carry perishable food such as fruit, fresh meat and vegetables up the Tigris without special transport. Towards the end of 1916 the transport was much improved and refrigerator barges with cold storage chambers for fresh meat, arrived and were of great value.

Until proper transport could be established field operation scales were in force; these scales were issued for short periods when the transport had to be limited.

Operation Scale—British Troops.

Biscuit	12 oz.
Preserved meat	12 ,,
Bacon	3 ,,
Potatoes or fresh vegetables	12 ,,
Dried vegetables or fruit when potatoes not available ..	3 ,,
Tea	1 ,,
Sugar	2½ ,,
Salt	½ ,,
Pepper	1/36 ,,
Cheese	3 ,,
Or butter (not to be issued more than twice a week) ..	2 ,,

Operation Scale—Indian Troops.

Atta or rice	1 lb. 4 oz.
Fresh meat	4 ,,
Or dhall	2 ,,
And ghi (when meat not available)	1 ,,
Condiments	¾ ,,
Salt	½ ,,
Dhall	4 ,,
Ghi	2 ,,
Gur or sugar	1 ,,
Potatoes or fresh vegetables	2 ,,
Tea	⅓ ,,

Chinese employed with the Mesopotamian Force received the following ration :—

Bread	12 oz.
Meat	12 ,,
Rice	12 ,,
Tea	1 ,,
Sugar	2 ,,
Salt	½ ,,
Pepper	1/36 ,,
Vinegar	1/30 pint.
Potatoes	4 oz.
Vegetables	4 ,,
Fresh fish	4 ,,
Peanut oil	1 ,,
Marmite	¼ ,,
Dhall (extra issue by C.Os., when required)	4 ,,

The Mauritius Labour Corps employed in Mesopotamia received the same ration as British troops.

Arabs and local inhabitants employed as mechanical transport drivers received the following ration :—

Atta or bread	1 lb.
Fresh meat	6 oz.
Or preserved meat	4 ,,
Milk	2 ,,
Rice	8 ,,
Dates	8 ,,
Ghi	2 ,,
Condiments	¾ ,,
Sugar	1½ ,,
Tea	⅓ ,,
Or coffee	⅔ ,,
Salt	½ ,,
Fresh vegetables	6 ,,
Fresh fruit	4 ,,
Lime juice (thrice weekly)	¾ ,,

The Arab and Persian Labour Corps ration was as follows :—

Atta	1 lb.
Rice	12 oz.
Ghi	2 ,,
Meat	6 ,,
Tea	⅓ ,,
Sugar	1½ ,,
Salt	½ ,,
Dates	8 ,,

The following table showing the number of cases of scurvy among Indian troops and the cases of beri-beri in British troops, indicates the effect of these changes in the ration scales :—

	Scurvy.	*Beri-beri.*
1916 (1st July to 31st December) ..	11,445 Indians.	104 British.
1917	2,199 ,,	84 ,,
1918	825 ,,	51 ,,

The incidence of scurvy reached a maximum in May and June 1916, and records showed that 335 cases of beri-beri had occurred among British troops up to the end of February 1916.

Colonel Willcox considered that the diminution in scurvy among the Indian troops must be attributed mainly to the supply of fresh vegetables and fruit contained in the rations issued at the end of 1916, and during 1917 and 1918. He also thought the issue of fresh meat had an important influence, especially in relation to British troops, who did not develop scurvy during 1916, when the troops, both British and Indian, were unable to get fresh fruit or vegetables for long periods, and yet the only protection which the British had as compared with that of the Indians was the fresh meat allowance of 1 lb. daily. Indians did not eat meat as a rule and usually had only a small daily ration. Tamarind was considered to have anti-scorbutic properties, but the lime juice issued up to the end of 1916 had no such value, as it was probably six months or more old before being issued.* In August 1916 fresh lime juice was prepared in India from fresh limes, a small quantity of alcohol and salicylic acid being added as a preservative ; this gave better results. After the capture of Baghdad lime juice was prepared from limes and bitter oranges obtained locally. It was issued to the troops with as little delay as possible.

The diminution in the number of cases of beri-beri amongst British troops was probably related to the addition of oatmeal and dhall to the British ration in July 1916, to the issue of marmite,† and to the issue at Colonel Willcox's suggestion of bread containing 25 per cent. of atta. After May 1917, the report of Miss Chick and Miss Hume on the germination of pulses having been received, germinated dhall was used in outlying districts when fresh vegetables or fruit could not be supplied and must have exercised a considerable influence in the prevention of both scurvy and beri-beri.

* See Diseases of the War, Vol. I, p. 419. † *Ibid.*, p. 440.

The history of the rationing of the troops in Mesopotamia brings out clearly two very important points :—

(1) That troops, especially Indian troops, taking the field must be physically fit and adequately nourished.

(2) That the quality of the field service ration is even of more importance than the quantity. If the necessary food substances are not properly represented in the diet the health of the troops becomes slowly undermined and much preventable sickness then results.

RATIONS IN NORTH RUSSIA.

The undoubted healthy state of the troops throughout a winter of a severity unknown before to European troops and the fact that only one case of scurvy* in the British force was observed during the entire campaign are outstanding testimonies to the sufficiency, liberality and suitability of the rations.

The original force which landed at Murmansk in June 1918 was not at first well fed. The diet lacked not only fresh meat and vegetables, but was in addition conspicuously monotonous. Biscuits, preserved meat, tinned milk, jam, tea, sugar, and rice formed the daily diet without variation. Lime juice was issued as an antiscorbutic three or four times weekly.

By the beginning of July, however, a definite and improved scale came into operation representing 4,431 calories per man daily. Variety was introduced and the number of calories increased. The following is the July ration in detail :—

Preserved meat 12 oz., or meat and vegetables	1	ration.
Flour	4	oz.
Biscuit	8	,,
Sugar	2	,,
Jam	3	,,
Bacon	4	,,
Cheese	2	,,
Dried vegetables	2	,,
Pea soup	1	,,
Pepper	$\frac{1}{100}$	,,
Mustard	$\frac{1}{100}$	,,
Salt	$\frac{1}{4}$	,,
Tea	$\frac{1}{3}$	,,
Milk	1	,,
Oatmeal	$\frac{1}{2}$	,,
Margarine	2	,,
Tobacco or cigarettes (weekly)	2	,,
Matches (weekly)	2	boxes.
Pickles (weekly)	3	oz.
Lime juice (four times weekly)	$\frac{1}{320}$	gal.
Rum	$\frac{1}{64}$	,,

* There were, however, three patients in hospital who developed symptoms of scurvy, but who were not noted as admissions for that disease. See Diseases of the War, Vol. I, p. 412.

With the advent of winter a further modification of the diet scale became necessary for troops working constantly over long periods of time and under climatic conditions which demanded above all things an undiminished manufacture of body heat.

The two features which required primary consideration in compiling a diet scale for troops operating in an arctic or sub-arctic latitude were the almost total absence of local supplies of fresh vegetables and the need of providing food of such a nature and in such quantity as to ensure the production within the body of a comparatively large amount of heat. Adequate during a short and hot summer, the July scale did not later fulfil these requirements, and the War Office, with the advice of Sir Ernest Shackleton, approved the following winter scale to commence in October :—

Meat	14	oz.
Or preserved meat or meat and vegetables	1	tin.
Bread	14	oz.
Or biscuit or flour	10	,,
Bacon	4	,,
Tea	½	,,
Or coffee	1	,,
Milk (tinned)	1	,,
Sugar	3	,,
Jam (or dried fruit)	2	,,
Salt	¼	,,
Pepper	$\frac{1}{100}$	,,
Mustard	$\frac{1}{100}$	,,
Oatmeal or rice	$1\frac{6}{7}$	,,
Cheese, margarine or lard	$3\frac{3}{4}$	,,
Peas or beans (not split)	$2\frac{3}{4}$	,,
Marmite or pea soup	½	,,
Pickles (thrice weekly)	1	,,
Tobacco or cigarettes (weekly)	2	,,
Lime juice	$\frac{1}{160}$	gal.

Heat-producing foods were readily obtained from England, but the great danger confronting the force was the lack of vitamine-containing food-stuffs. Whilst in summer it was possible to cultivate green vegetables in North Russia, the unsuitability of the soil generally and the resultant attenuated growth proved at once the uselessness of seeking locally for a solution of the problem. Although lime juice had been included in the diet scales, its value as an anti-scorbutic, and consequently as a real substitute for fresh vegetables, had then become seriously questioned as a result of Miss Chick's investigations. The War Office, therefore, in arranging the winter scale included a liberal issue of whole peas or beans with the object of ensuring that a vitamine-containing diet would

be available for all troops in whatever portion of the occupied area they might be situated. The germination of the pulses was a simple operation and one which was generally effectively undertaken whenever intelligent control was exercised. The entire force adopted this method. Not only in this way were the essential vitamines made available but the process of preparation greatly enhanced the palatability of the food. Meanwhile locally it was considered wise to maintain the daily issue of lime juice, and with the arrival of larger consignments of sugar from England the sugar ration was augmented to sweeten the lime juice and thus to ensure its consumption with greater certainty.

The winter scale was one which compared favourably with the field ration on the Western front. Indeed, whilst the field ration in France contained 4,044 calories, the North Russian winter scale gave as many as 4,217 calories. At first it was thought that cheese would rapidly deteriorate in these latitudes, but this proved not to be the case. Oatmeal was included to add variety and to replace rice from time to time. Dried vegetables for a similar reason were included, although it was realized that they had no antiscorbutic value.

Whilst the Archangel force was well satisfied with the winter scale from all points of view, the authorities of the Murmansk force, operating some two or three hundred miles north-west, recommended that the flour and biscuit should be increased to 13 oz. and bread to 18 oz., on the grounds of exposure to extreme cold combined with the hard physical exertion. Additions, however, were made to apply to both forces and included 8 oz. of fresh potatoes thrice weekly, 4 oz. of onions or other root vegetables twice weekly, 4 oz. of oranges or lemons twice weekly, and ½ oz. of cocoa daily. Finally, fresh potatoes were issued daily and fresh meat on four days weekly or oftener, as stocks allowed.

It was not until the early summer of 1919 that fresh vegetables and fruits arrived in Archangel from England. The first consignments were found to be unfit for distribution to the troops in the forward areas. Two factors contributed to this, and had reference only to the Archangel force. The White Sea was navigable only by ice-breakers between the months of November and May. For transportation reasons, supplies for Archangel were in the first instance taken occasionally, if not frequently, to Murmansk. In this respect unavoidable delay occurred at Murmansk, owing to the store ships from England with supplies for Archangel being unsuitable in

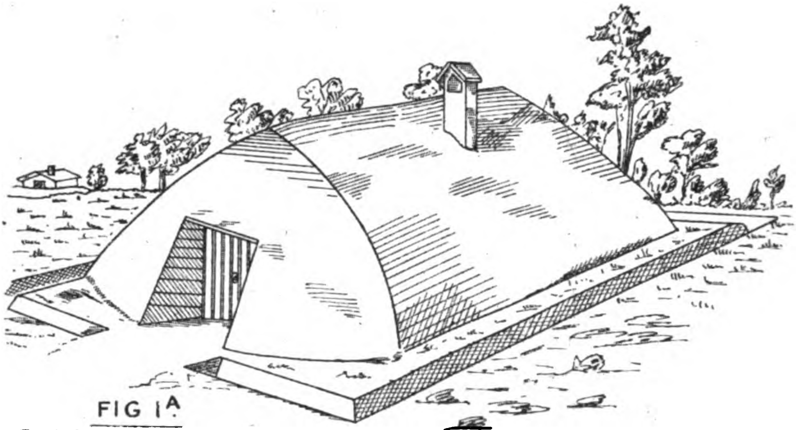

FIG 1A.
PERSPECTIVE SKETCH

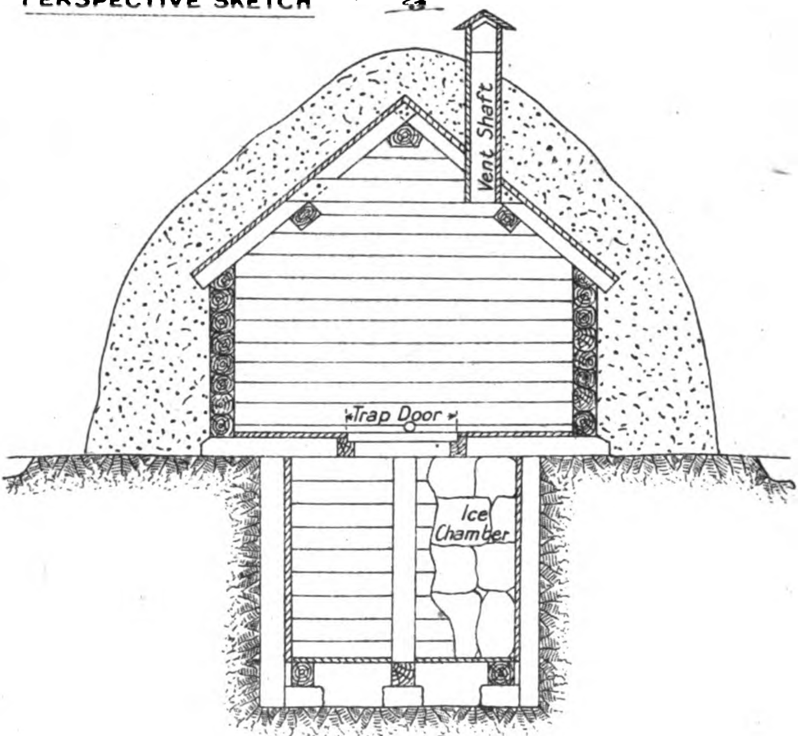

FIG. 1B.
CROSS SECTION

DESIGN FOR AN ICE HOUSE.

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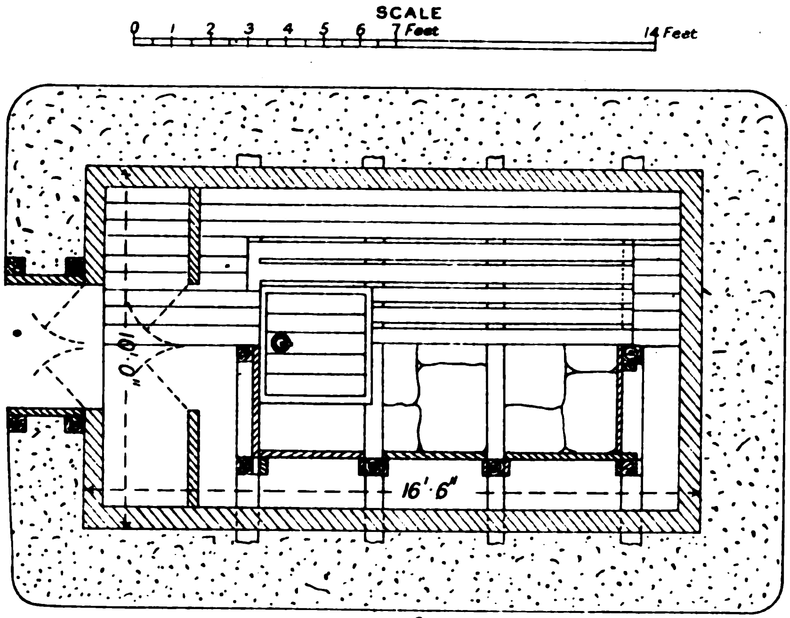

FIG. 1c
PLAN.

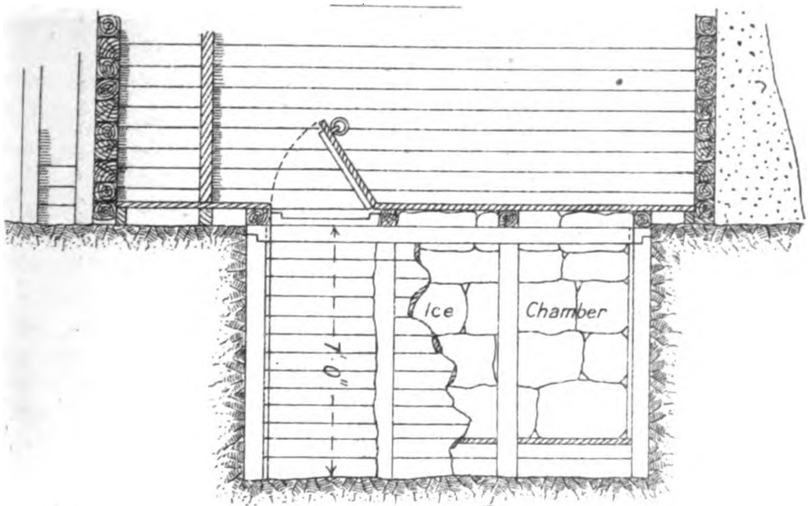

FIG. 1d
LONGITUDINAL SECTION.

DESIGN FOR AN ICE HOUSE.

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structure to undertake the passage of the ice-bound White Sea. Transhipment therefore to ice-breakers became necessary. Ice-breakers were not then always available for the transhipment of stores and a delay of several weeks might thus easily occur. In the winter months the time occupied in the sea passage from Murmansk to Archangel varied from three days to as many weeks.

After unloading at Bakharitza, the port of Archangel, perishable stores had to be reloaded on barges, or on sleighs if the river was not then open. The headquarters of the river force at Beresnik was four days distant from the base by river communication, whilst on sleigh the journey took somewhat longer. Under winter conditions, therefore, weeks elapsed before fresh perishable stores could reach the troops occupying the front line of the river force. The short summer, too, was intensely hot, and fresh meat issued from the refrigerators of the storeships or from the central refrigerators in Archangel became unfit for food after being twenty-four hours on the journey to Beresnik, roughly a quarter of the distance to the outlying troops. Frozen meat during conveyance to the outlying troops thawed on the surface and on refreezing became mouldy. In some instances it was then considered unfit for consumption, but when the mould was removed the meat was palatable and wholesome. In three months the troops in this particular part of the line received fresh or frozen meat on three occasions only.

These transport difficulties necessitated the erection of ice-houses to provide cold storage throughout the summer (Fig. 1), but unfortunately much of their efficiency was impeded by lack of adequate provision for ventilation. Ice houses were in some situations available locally. As a rule they were underground sheds well insulated with earth and packed with ice. Archangel had large cold storage in a substantial building which was taken over by the British military authorities. Murmansk, on the other hand, had to depend on the local underground ice-packed sheds, insulated freight wagons, and the S.S. "Nigeria," which was berthed at the quay-side. There was no doubt that during summer cold storage barges for river transport of perishable stores would have been at once invaluable and economical.

French, American, Italian, Serbian and Polish troops enjoyed the same scale of ration as the British troops, with certain minor differences.

There was also a special ration scale for locally enlisted Russian troops. The items of the scale were less numerous than those forming the British and allied scale, but the issue of bread, flour and biscuit was more liberal, whilst herrings were added and the quantities of other articles reduced.

The adoption of ration sheets by units and detachments was insisted upon with a view to ensuring variety in the meals. In the earlier months of the campaign this measure could not, however, be carried out, since the rations available did not allow of variation. Later, when the ration sheets were brought into use, variety was a noteworthy feature of the daily diet. The arrival in the later months of 1918 of the staff of the Army Canteen Board with large supplies assisted considerably in the variation of the diet in many messes.

Certain articles of food were obtainable locally, such as fresh fish, smoked salmon, reindeer flesh and game. In this respect the Archangel Force was not so happily placed as the troops in the Murmansk Area. Game, smoked salmon and fresh fish were frequently obtainable, whilst occasionally large supplies were requisitioned from the Petchova district, but at no time could they be considered constant.

The inhabitants existed mostly on bread, which until the arrival of the allied force was of a very inferior character. For example, a small quantity of flour obtained from a small village in the neighbourhood of Onega was found to consist entirely of powdered straw. Smoked salmon, eaten uncooked, was a favourite dish. The more substantial civilians were able to purchase tinned foods, usually sardines or similar small fish. Veal was procurable though expensive and was popular amongst the Russians. Tea and vodka were the popular beverages. Very frequently the Russian drinks tea of weak infusion well diluted with boiling water to which jam made from edible "tundra" berries was added, presumably as an anti-scorbutic.

Mobile forces which operated as detached columns for shorter or longer periods were provided with a special ration of higher calorie value and easy of transport. For the preparation of this ration the War Office had consulted Sir Ernest Shackleton, its composition being similar to that used in the trans-antarctic expedition.

The special part of the ration was a composite preparation put up in 1-lb. cakes, each cake providing sufficient food for one meal for two men. For supply and transport each cake was

wrapped in parchment paper and packed in oblong tin-lined boxes. The cake contained the following ingredients :—

Oatmeal	4 oz.	(472 calories)
Icing sugar	1 „	(116 „)
Beef powder	3 „	(332 „)
Lait-proto (casein)	1 „	(98 „)
Oleo	7 „	(1,846 „)

Eight ounces of this mixture contained 1,432 calories, an amount which had to be consumed twice daily by each man. Although perfectly palatable and sustaining when eaten cold, the cakes were most frequently heated with snow to a liquid " hoosh."

Ice-chips were put into a cooker and, when the ice became partially melted, the cake was put in. When boiling, or nearly so, the meal was ready, half a pint of " hoosh " being given to each man.

Nut food, sugar, " Trumilk," tea or yerbe matte, marmite, lime juice and salt were added to the ration. Nut food was prepared by a firm in England and consisted of a mixture of fruit and nuts made up into cakes weighing 8 oz. Sugar was additional to that contained in the cakes. " Trumilk " was in powder form. Yerbe matte was specially obtained from Brazil and is superior to tea in that it is a greater stimulant and useful as a restorative in conditions of fatigue. The marmite issued with the supper meal was spread on biscuits or used to flavour the " hoosh."

This ration for a mobile force was made to serve the following three meals daily :—

Breakfast.

Special ration	8 oz.	(1,432 calories.)
Biscuit	1 „	(105 „)
Sugar (additional)	1¼ „	(174 „)
Trumilk	2 „	(300 „)

Lunch.

Biscuit	5 oz.	(525 calories.)
Nut food	8 „	(1,124 „)
Trumilk	¼ „	(35 „)
Tea	¼ „	

Supper.

As for breakfast but with marmite (¼ oz.) in addition (2,011 calories).

Lime juice	1 oz.
Salt	⅛ „

The total value of the ration was 5,706 calories, and was sufficient to sustain a strong healthy man undertaking both mental and physical labour under conditions of extreme cold. It was thoroughly nutritive, antiscorbutic, and had laxative properties.

Scurvy was noticed amongst the poorer inhabitants shortly after the arrival of the original force at Murmansk in June 1918. The local hospitals contained many cases of the disease, whilst many individuals occupying different barracks in the town were found to be similarly affected. The disease did not at first appear to prevail to the same extent in Archangel, but an examination of the persons detained in the civil prison indicated that generally the food resources locally were insufficient to maintain the health of most of the inhabitants.

Much valuable work, particularly in the forward areas and amongst the locally enlisted troops, could have been done by the appointment of messing or catering officers to supervise the issue and preparation of the ration. In the absence of such officers, arrangements were made in October 1918 for the establishment of a school of cookery. A site was found in the large Russian naval barracks at Solombola and many selected men, both British and Russian, were instructed in the preparation of the ration into nutritious and palatable dishes. The course included the structure and management of different types of improvized ovens and fire-places, and the services of a French chef were enlisted. Men selected for instruction at the cookery school were in the first place bacteriologically examined to ensure that no one commenced this course who was a "carrier" or an ambulant case of a communicable intestinal infection.

The type of kitchens or cookhouses used by the troops varied considerably. In many cases, especially in the forward areas, the accommodation was far from satisfactory. Too often the kitchens at the billets were used to serve the needs of both the troops and the Russian inmates.

The cooking arrangements usually found in the kitchen of the ordinary Russian dwelling-house consisted of a fireplace built to serve all purposes, oven, hot-plate and boiler. Every Russian house baked its own supply of bread, and consequently the greater portion of the range or kitchener was occupied by a large bread oven. The range was a square brick-built white marbled type of fireplace abutting on to the floor and extending well into the room. It was, as a rule, a bulky structure. The bread oven was arched and deep and heated

by burning wood on the floor of the oven. The smaller portion of the range contained a long narrow fireplace over which was placed the hot-plate and with which was incorporated an open metal boiler. Occasionally, for the purpose of roasting, a small iron oven was inserted so as to occupy a position at the back of the bread oven, the flue from the fireplace passing round it on its way to the chimney.

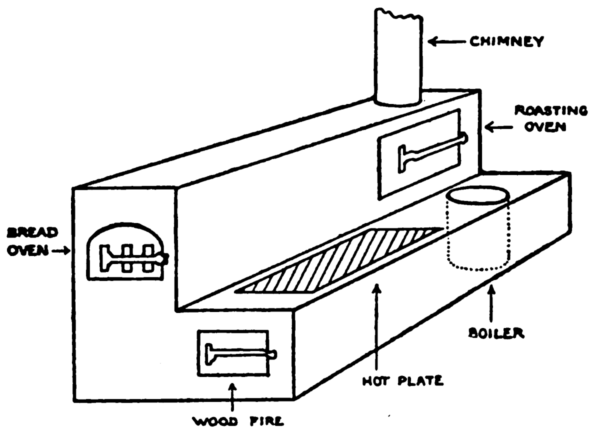

FIG. 2.- RUSSIAN OVEN.

The cooking arrangements in Russian barracks were similar to those described above but naturally on a larger scale. Frequently, however, hot-plates and ovens were omitted, giving place to a service of 30-gal. boilers built into the brickwork.

In many cases adaptation of the existing arrangements to meet the requirements of the troops was necessary. In billets nothing further than the fitting of the iron roasting oven and extension of the hot-plates were required. In the barracks, however, the preparation of the British diets required more appliances than were usually available. Thus, iron ovens were inserted into the brickwork, hot-plates fixed for pot-boiling, and new flues erected.

Kitchens in the forward areas and on the lines of communication conformed to those of ordinary billets. Sometimes the accommodation had to be reinforced, and some Russian military field cookers discovered at Archangel were dispatched by water and rail transport to various portions of the advanced line.

Russian railway wagons were converted into kitchens by the installation of boilers, small Russian stoves with oil drum ovens, and preparation tables.

In certain circumstances the Royal Engineers erected cookers in accordance with plans drawn up by the officer commanding the sanitary section. It was a brick erection, providing accommodation for four degchies and one good-sized oven.

In summer, rough cookhouses were erected in the open and conformed generally to the usual military type of field kitchen. Men living in blockhouses arranged to do their cooking on the small Russian stove placed in the centre of the room.

During the fly season, units were urged to make arrangements for the adequate protection of food, and illustrated circulars indicating simple measures to effect this were circulated throughout the force.

CHAPTER III.

PREVENTION OF FOOD DEFICIENCY DISEASES.

AT a meeting of the Army Sanitary Committee at the War Office in January 1916, Lieut.-Colonel Willcox reported that several cases of beri-beri had occurred on the Gallipoli Peninsula, and that yeast, haricot beans, and oatmeal had been found most successful in the treatment and prevention of the disease. Yeast, recommended by Major C. J. Martin of the Lister Institute, was by far the most efficient. Cooper, working in the Lister Institute in 1913, found that half a grain of pressed yeast sieved and then dried at 37° C. for two days was sufficient to maintain pigeons, fed on polished rice, free from polyneuritis for fifty days and to prevent any loss in weight. Schaumann also ascertained that an alcoholic extract of yeast had a similar effect, but loss in weight was not prevented. It was therefore decided early in 1916 that enquiries should be made as regards the best form in which yeast could be supplied, as well for preventive as for curative measures. Professor E. H. Starling, at that time in charge of the Hygiene Department at the Royal Army Medical College, was asked to report on the various preparations of yeast on the market; he ascertained that a desiccated yeast in the form of threads, guaranteed to keep for three months, and a desiccated yeast specially prepared for the tropics, could be obtained. He suggested the following specification: " Yeast to be distillers' yeast of good quality, thoroughly air-dried, at a temperature not exceeding 40° C. (104° F.), the yeast to be still alive, capable of vigorous growth and fermentation. To be packed in hermetically sealed tins, each containing 1 lb." One pound of dried yeast was considered to supply a week's ration for sixty-four men.

Arrangements were then made to send a large supply of dried yeast to Mesopotamia, as the Commander-in-Chief, India, reported that up to February 1916 there had been 342 cases of beri-beri amongst the troops, and he was unable to obtain air-dried yeast in sufficient quantities in India.

In June 1916, the officer then in charge of the Hygiene Department of the Royal Army Medical College, Lieut.-Colonel Monkton Copeman, reported that a commercial extract of yeast, marmite, had distinct advantages over yeast in that it remained practically unchanged even when exposed to the air,

while yeast preparations deteriorated and in some cases underwent putrefactive changes; its bulk also was much smaller. Marmite is a pure extract of yeast made by submitting purified brewers' yeast to a special digestive process and then evaporating it down under reduced pressure to the required consistency. The resulting product is almost indistinguishable in appearance, smell, and flavour from extract of meat. Chemically, apart from the question of vitamines, it differs from extract of meat in not containing any creatine or creatinine. Analyses of two preparations of unflavoured marmite gave the following results:—

	Marmite 1.	Marmite 2.
Water	28·2	32·5
Ash	20·5	17·6
Nitrogen	5·5	5·2
Ammon. N.	1·7	1·5
Acidity = lactic acid	9·7	8·4
Phosphoric acid:—		
Total P_2O_5	6·3	6·1
Inorganic P_2O_5	4·4	4·0
Organic P_2O_5	1·9	2·1
Coffee	0·01	0·01

Miss Chick and Miss Hume in their work on the distribution of anti-beri-beri vitamines found that marmite was amongst the potent substances tested.

As a result of a conference with the manufacturers and many tests in the Royal Army Medical College, a solidified preparation of marmite was produced and put up in half-ounce cubes or tablets which were so flavoured that they could be eaten in this form, or if preferred, with bread or biscuit. The tablets could also be used for making soup. They each contained 50 per cent. of marmite, or ¼ oz. in each cube, which represented the active vitamines in 3½ oz. of yeast; consequently the eating of half a tablet twice a week apparently sufficed for prevention of beri-beri, the rations issued being otherwise not absolutely devoid of vitamine. One tablet daily would be necessary in a diet devoid of anti-neuritic vitamine.

The marmite rations were made according to the following formula:—

Marmite, plain (minimum salt)	35 parts.
Marmite S_2 Extract*	15 ,,
Cane sugar (syrup, saccharometer 220°)	7·5 ,,
Pea flour (Symington's high-pressure steam-prepared) ..	50 ,,

* Marmite S_2 extract consisted of two-thirds marmite and one-third of a highly concentrated essence of onion, carrot, and aromatic herbs, with a small percentage of garlic and of bacon extract.

The amount of copper in the ration was not to exceed 1 in 20,000 parts.

Five thousand pounds of the marmite ration were sent to the General Officer Commanding, Basra, in August 1916, and 3,000 lb. monthly from October onwards. The supply in November was increased to 10,000 lb. monthly. A quarter of an ounce of marmite was ordered to be given as a ration three times a week during the winter months. All samples sent to Basra were carefully inspected by officers of the Hygiene Department and specimens were examined in the laboratory for the presence of copper.

In September 1917, the Commander-in-Chief, India, pointed out that as marmite contained bacon fat, it could not be issued to Indian troops on account of caste prejudices, and requested an alternative preparation to be devised. Experiments were made and tablets prepared with vegetable fat and without fat. Tablets made without fat were found rather bitter, but those made with cotton-seed oil were quite satisfactory. These accordingly were then issued for general use.

In January 1916, Miss H. Chick and Miss E. M. Hume commenced work at the Lister Institute on the distribution of anti-beri-beri vitamines, as the result of letters from Major C. J. Martin, Director of the Lister Institute, who at that time was in Lemnos, acting as pathologist of No. 3 Australian General Hospital. Major Martin diagnosed beri-beri in some patients in hospital on the island, and wrote to the Lister Institute about the value of various food-stuffs.

On 9th June, 1916, Miss Chick and Miss Hume submitted to the Officer-in-Charge of the Hygiene Department, Royal Army Medical College, a " Preliminary note of the results obtained in the investigation of the anti-neuritic properties of various food-stuffs, especially those suitable for the rationing of troops on active service." In this report Miss Chick and Miss Hume stated that as far as is at present known, deficiency diseases appear to be of two classes, producing on the one hand the symptoms characteristic of scurvy, and on the other, diseases marked by nervous lesions, of which beri-beri is the well-known example. There is some evidence that these two conditions result from a deficiency in the diet of two separate classes of " vitamines," whose distribution among food-stuffs may also be distinct. For example, the anti-scorbutic " vitamine " is known to be present in the juices of fresh fruit, and to be destroyed by heat at a temperature considerably below that of boiling water. The anti-neuritic " vitamine " has not so far

been demonstrated to exist in any amount in fruit parenchymatous tissue; it can withstand the temperature of boiling water for some considerable time. The experiments detailed below are concerned with the study of the anti-neuritic "vitamines" alone.

The polyneuritis induced in pigeons by a diet of polished rice has been accepted as analogous to beri-beri in human beings. The anti-neuritic properties of the various substances have therefore been studied by means of feeding experiments with pigeons and a comparative measure of their "vitamine-content" was obtained by the following two classes of experiments. These form a continuation of those of Cooper, and the same methods have been employed.* Feeding was artificial in both cases.

Preventive Experiments.—The object of these experiments was to determine the minimum amount of the food stuff that must be added to a vitamine-free diet in order to prevent the occurrence of polyneuritis. Polished rice, 40 grm. daily, formed the vitamine-free diet, and prevention was reckoned to be successfully accomplished if the bird showed no symptoms of polyneuritis after fifty to sixty days. Unprotected birds usually develop neuritis within fifteen to twenty-five days.

Curative Experiments.—In these experiments determination was made of the minimum amount which, administered by the mouth, would cure a bird suffering from acute polyneuritis. A bird in this condition, brought on by an exclusive diet of polished rice, will usually die within twelve hours if not treated. In order to get the required amount of curative substance absorbed in time, it was usually necessary to concentrate the vitamines in the food-stuffs under investigation. This was done by extracting the air-dried material by absolute alcohol in the cold and evaporating the alcoholic extract to dryness at a low temperature (30° to 40°) under reduced pressure. The residue was then taken up in a small measured volume of water and definite quantities were given by the mouth. In order to institute a fair comparison, the doses given were reckoned in terms of the original food-stuffs. Concentration was not necessary in the case of marmite.

The endosperm of wheat (equivalent to white flour) has not yet been examined, as it appeared unnecessary. The researches of Holst and of Simpson and Edie have shown that, whereas

* In the tables following the results obtained by Cooper are added for purposes of comparison.

a diet of whole meal bread or "Standard" bread, both of which should contain germ and bran, will protect pigeons from polyneuritis, white bread induces the disease in the same way as polished rice. The object of the investigation was to decide whether the anti-neuritic vitamine was situated in the germ or the cuticle (bran).

TABLE I.

Minimum Daily Ration which must be added to a Diet of Polished Rice to prevent the onset of Polyneuritis in Pigeons of 300 to 400 grm. weight.

Substance.	Daily Ration.		Result.
	Natural. Food-stuffs.	Dry Weight.	As regards Weight of Pigeon.
	Grm.	Grm.	
Marmite, commercial "unflavoured."	0·5	0·35	Loss of weight.
Wheat germ, not cooked	1·0	0·87	Weight maintained.
Wheat germ, "Hovis" commercial, cooked.	1·5	1·3	,, ,,
Pressed yeast	2·5	0·5	,, ,,
*Lentils	—	3·0	Loss of weight.
*Barley, unhusked ..	3·7	3·2	,, ,,
*Barley, husked ..	5·0	4·5	,, ,,
*Egg-yolk	3·0	1·5	,, ,,
*Beef muscle	20·0	5·0	Weight maintained.
*Ox heart muscle ..	5·0	1·7	,, ,,
*Ox brain	6·0	1·2	Slight loss of weight.
*Ox liver	3·0	0·9	Loss of weight.
*Sheep brain	12·0	2·5	Weight maintained.
*Fish muscle	More than 10	More than 2	
*Cheese	,, ,, 8	,, ,, 5·6	
*Cow's milk	,, ,, 35	,, ,, 3·5	
*Wheat germ (sample R.I) free from bran.	1·5	1·3	Complete protection, weight maintained.
Wheat bran (sample R.I) free from germ.	1·5	1·4	No protection, birds developed polyneuritis in same period as controls.
Wheat bran (sample A) stone-milled, probably not free from germs.	5·0	—	Protected from polyneuritis, weight maintained.

N.B.—These experiments were carried out by Miss Chick and Miss Hume; the results obtained by Cooper, marked *, were published in the *Journal of Hygiene*, 1913–14.

TABLE II.

Minimum Amounts of various Food-stuffs required to cure Acute Polyneuritis in Pigeons, 300 *to* 400 *grm. Weight. The Doses are reckoned in terms of the original Food-stuffs.*

Substance.	Preparation of Curative Material.	Amount of Dose given. In terms of the Natural Foodstuffs.	Amount of Dose given. In terms of Dry Weight (Dried 100–110°C).	Result.
		Grm.	Grm.	
Wheat germ, commercial, cooked, "Hovis."	Extracted with alcohol	8	6·9	Improvement, no cure.
	do. do.	12	10·3	Complete cure.
	do. do.	12	10·3	Incomplete cure.
	do. do.	16	13·8	Complete cure.
	do. do.	16	13·8	do.
	do. do.	20	17·2	do.
	do. do.	20	17·2	do.
	do. do.	20	17·2	do.
Wheat germ, "picked germ," uncooked.	do. do.	10	8·7	Incomplete cure.
	do. do.	15	13·0	Complete cure.
	do. do.	15	13·0	do.
	do. do.	20	17·4	do.
Pea flour, (Pearce, Duff & Co.), "kilned."	do. do.	40	—	Slight improvement, no cure.
	do. do.	40	—	do.
	do. do.	80	—	do.
Wheat germ (sample B)	Given without extraction in small pills made with water, thus avoiding great loss of extraction	1–2	0·9–1·8	Cured.
Maize germ	do. do.	1–3	0·6–1·8 (approx.)	Cured.
Rice germ	do. do.	1	—	Complete cure.
Fish roe	Extracted with alcohol	35	10	Cure almost complete.
	do. do.	70	20	Complete cure.
Turbot (hard)	do. do.	140	40	do.

" Vitamogen "	Given without extraction	12	—	No improvement, died.
	do. do.	31	—	Temporary improvement.
*Egg-yolk	Extracted with alcohol	60 (= 4 egg yolks)	30	Cure.
Dried whole egg, " Eggo "	Given without extraction	40 (= about 4 eggs)	38	do.
	do. do.	30 (= about 3 eggs)	29	do.
*Malt extract:				
1st sample	do. do.	5	4·2	do.
2nd sample	do. do.	7	5·1	do.
3rd sample	do. do.	10	9·2	No cure.
Meat extract (Liebig's)	do. do.	3	—	No improvement, bird died.
*Raw beef	Extracted with alcohol	140	30 (approx.)	Cure.
Meat extract (Liebig's)	Given without extraction	6·5	5·2	No improvement, bird died.
Dried peas, " Clipper "	Extracted with alcohol	30	26	Incomplete cure.
	do. do.	40	35	Complete cure.
Dried lentils	do. do.	20	—	Cure.
Dried vegetables, Rural Products Co.	do. do.	40	—	Cure.
Spring greens	do. do.	120	—	Complete cure.
Potatoes, peelings	do. do.	180	36	Died.
	do. do.	630	126	Improvement, not cured.
" insides	do. do.	200	40	Incomplete cure.
	do. do.	350	70	Cure.
Pressed yeast	Autolysed.	2·0	—	Cured slowly.
	do.	3·0–6·0	—	Cured.
Marmite, commercial unflavoured	Given without extraction	1·5–2·0	1·0–1·5	Complete cure.
" Maconachie " ration	Extracted with alcohol	442	106	Cure incomplete.
Dried fruits, currants	do. do.	60	—	No improvement.
	do. do.	19	—	do.
" dates	do. do.	26	—	Slight improvement, death delayed.
	do. do.	26	—	Slight temporary improvement.
" New Ration " roast beef tinned, submitted for examination by the Dept. of Hygiene, R.A.M. College on 19.6.16.	Extracted with alcohol	350	112 (approx.)	Very slight improvement. No cure.

* Cooper, 1913–1914.

TABLE III.

Influence of High Temperatures upon the Curative Properties of Wheat Germ and Yeast Extract. The Tests were made upon Pigeons (300 to 400 grm. weight) suffering from Acute Polyneuritis induced by a Diet of Polished Rice. Heating was done in a Steam Autoclave.

Material.	Water Content.	Temperature.	Time of Heating.	Amount of Dose given. In Terms of Natural Food-stuff.	Amount of Dose given. In Terms of Dry Weight.	Method of Administration.	Result.
	Per cent.	° C.	Minutes.	Grm.	Grm.		
Wheat germ, (sample B.)	11	Control not heated.		2·5	2·2	As pills made with water, by the mouth.	Complete cure.
				1·5	1·3		Cure not always complete.
				1·0	0·9		Cure in 3 cases out of 5.
	13	90–100	40	5·0	4·3	do. do.	Complete cure.
				2·5	2·2		Cure in 2 cases out of 4.
		98–103	120	2·5	2·2		Complete cure in 2 cases out of 3.
	14	110–117	60	10·0	8·6	do. do.	Complete cure.
				5·0	4·3		Cure in 2 cases out of 3.
				2·5	2·1		Improvement in symptoms, no cure.
	12·5	118–124	120	10·0	8·8	do. do.	Delayed death, slight improvement, no cure.
				5·0	4·4		Slight improvement, not cured.
Yeast extract, (sample M.)	Original extract contained 30 p.c. water, solution heated contained 35 p.c. solid and 65 p.c. water.	Control not heated.		2·0	1·4	Placed directly in the crop by means of a syringe in the mouth.	Cure.
				1·5	1·0		Cure.
				1·0	0·7		Cure (?) complete.
	do.	100	60	3·0	2·0	do. do.	Cure.
				2·0	1·4		Cure in 1 case out of 4; the rest incompletely cured.

In Table III are given the results of experiments to investigate the influence of high temperatures upon the anti-neuritic properties of wheat "germ."

On 30th October, 1916, Miss Chick and Miss Hume submitted a "second preliminary note of the results obtained in the investigation of the anti-neuritic properties of the various food-stuffs, especially those suitable for the rationing of troops on active service." In this note the information contained in the first report was repeated and further results were discussed. As regards cereals, it was stated that in the case of all three types studied—rice, maize, and wheat—a considerable amount of anti-neuritic substance is contained principally, if not entirely, in the germ. The well-known influence of decorticated rice in inducing beri-beri, and the prevention and cure of the disease by the use of "rice polishings," Miss Chick and Miss Hume believe to be explained by the fact that in the milling of the rice the germ is removed with the bran. In modern methods of milling wheat, *e.g.*, in roller mills, the separation of the germ is so complete that unless special precautions are taken to return a proportion subsequently, as in "Standard" flour, it may be assumed that the white flour obtained is free from that valuable constituent. The practical necessity of including the wheat germ in flour from which bread or biscuit is made is self-evident when these are intended for troops on active service who may be separated from fresh food supplies. This is the more urgent seeing that the rest of the ration will consist principally of tinned foods, which, owing to their previous sterilization, are also deficient in these vitamines.

As regards the influence of high temperatures, the results in Table III show that during the heating to 100° C. for about one hour the anti-neuritic properties of wheat germ are slightly diminished; in the neighbourhood of 120° C., however, the deterioration is much more rapid. The experiments at or near 100° C. were devised to be comparable with ordinary cooking processes, those near 120° C. to throw light upon the probable fate of anti-neuritic vitamines during the sterilization of tinned food, *e.g.*, tinned meat. In this connection it is interesting to compare the curative values given in Table II of raw beef, in which a curative dose was equivalent to 30 grains dry weight, and of a "Maconachie" ration and the "New" army ration, in which no cures were obtained with extract equivalent to 106 and 112 grains dry weight respectively.

The destructive effect of high temperature upon the anti-neuritic vitamine is also seen by comparing the curative

properties of unheated or dried peas and "kilned" pea flour respectively in Table II. This fact needs emphasis, since many samples of pea flour on the market have been kilned in the process of preparation, although no mention is made of this fact on the wrappers.

The most important points contained in Miss Chick's reports were communicated to the Commander-in-Chief of the Mesopotamian Forces, who ordered the issue of marmite twice a week during the winter months, commencing October 1916. Colonel Willcox, the consulting physician to the forces, instituted experiments to determine the practicability of issuing to British troops bread made with a certain proportion of atta in the flour. Bread made with 25 per cent. atta, a coarsely milled flour rich in anti-beri-beri vitamines, was found quite palatable and differed little, except in the slight brownish colour, from ordinary bread. A general issue of this bread three days a week was then sanctioned, and was an important factor in the reduction of beri-beri amongst troops.

On 27th February, 1917, Miss Chick and Miss Hume submitted a third report in which a summary of their previous work on the prevention of beri-beri was given, and also the results of an investigation of the army biscuit with reference to its value in the prevention of beri-beri and experimental work on the prevention of scurvy.

The results of the investigation of army biscuit are given in Table IV.

The results with white wheat flour given in Table IV confirm the observations of Holst and Simpson and Edie and show that, when used as sole diet, beri-beri is occasioned in the minimum time, in the same manner as with polished rice, namely, in about twenty days. Miss Chick's and Miss Hume's work upon the amount of germ or bran which it is necessary to add to a diet of polished rice in order to keep a bird in health indicated that little of the germ and bran of the whole meal could be withdrawn from a diet of wheat without symptoms ensuing.

They were therefore surprised to find that even biscuit II, type (*b*), of "pure wheat flour," contained sufficient anti-beri-beri vitamine to prevent the development of symptoms. The only explanation they offer is that the "pure wheat flour" in the specification, as interpreted by the contractors, is not comparable with the specimen of white flour used in the experiments. They consider it highly desirable that the formal specification should be altered to ensure that all biscuit destined

for use by troops on active service should be composed either entirely of whole wheat meal, or of wheat flour to which an adequate proportion of wheat germ has been added.

TABLE IV.

Influence upon Pigeons (400 grm. weight) of Diets consisting exclusively of White Flour, Polished Rice, Quaker Oats and Army Biscuit.

Article.	Result.	Period of Experiment. Days.	Change in Weight during Period of Experiment.
Pure white wheat flour..	Birds developed acute poly-neuritis.	19	Decrease 30 per cent.
Polished rice	do. do.	23	„ 18 „
Quaker oats	Birds remained in good health.	63	Increase 2 „
Army biscuits :— I. " Button ".. ..	do. do.	63	„ 4 „
II. " Pure Wheaten " (specification type (*b*) " pure wheat flour.")	do. do.	63	Decrease 4 „
III. "Wheatmeal" (specification type (*a*) containing " $\frac{2}{3}$ pure wheat flour and $\frac{1}{3}$ whole wheat meal.")	do. do.	63	Increase 1 „
IV. Experimental, prepared from pure white flour, with the addition of 7 per cent. wheat germ previously steamed.	do. do.	63	„ 5 „

The same principle would apply to flour supplied to the army for bread-making under conditions in which the troops are separated from fresh food supplies.

As regards their investigations on anti-scorbutic elements in food-stuffs, Miss Chick and Miss Hume reported as follows :—

The anti-scorbutic vitamine, or the substance whose deficiency in a diet occasions scurvy, appears to differ from the anti-beri-beri vitamine in its distribution and properties, as well as in the nature of its influence upon nutrition.

While there exists a good deal of empirical knowledge upon this subject, the sources of accurate scientific information are very few, and are to be found chiefly in the work of Professor Axel Holst and his colleagues, Drs. Fürst and Fröhlich, at the University of Christiania. By depriving guinea-pigs of fresh green food and offering only a diet of grain and water, these workers induced a disease analogous to human scurvy, from which the animals died within a month. By studying the influence of various additions to this diet, they were able to investigate the distribution of the anti-scorbutic principle among various food-stuffs and its resistance to drying, heat, and other influences.

The anti-scorbutic vitamine is much less wide-spread among food-stuffs than the anti-beri-beri vitamines and is much less stable, displaying greater sensitiveness to the influence of drying, or high temperatures. Its presence seems to depend on association with the living plant or animal cell in connection with which it is produced.

All dry food-stuffs are deficient in anti-scorbutic vitamine. The tissues of fresh vegetables dried at low temperatures or their expressed juices preserved in the cold rapidly lose their anti-scorbutic properties. The juices of fresh fruits, however, were found to be distinctly more stable in respect to this character, a result which is in accord with the general opinion as to the value of preserved fruit juice, *e.g.*, lime juice.

When boiled at 100° C. cabbage was found to lose about one-half its anti-scorbutic value in thirty to sixty minutes; at 120° C. this property was entirely destroyed in one hour. Under these conditions no anti-scorbutic vitamine may be expected to survive the sterilization to which tinned foods are subjected.

The observations of Holst and his co-workers were extended in the direction of food-stuffs which are convenient for transport and hence suited for the rationing of armies. Miss Chick and Miss Hume were assisted in this work by Miss Ruth Skelton, Dr. E. M. Delf, and Miss Olive Lodge. They have not yet succeeded in obtaining quantitative results, similar to those obtained in the investigation of anti-beri-beri vitamines. Enough information is, however, available from the data and those of the Norwegian workers to draw up a table (Table V) in which a rough estimate is given of the comparative value of the commoner classes of food-stuffs against beri-beri and scurvy.

TABLE V.

Value of Food-stuffs as preventive against Scurvy and Beri-beri.

Food-stuffs.	Water Content per cent. (approx.).	Value against Beri-beri.*	Value against Scurvy.*
Cereals—			
Whole grain (wheat)	10 to 13	+ +	0
Endosperm, *e.g.*, polished rice, white flour (wheat)		0	0
Bran, *e.g.*, rice, wheat		+ +	0
Germ or embryo, *e.g.*, rice, wheat ..		+ + +	0
Pulses—			
Whole, in dry condition	12	+ +	0
Germinated pulses (or cereals) ..	50	+ +	+ +
Vegetables—			
Potatoes	80	0	+ +
Fresh, *e.g.*, cabbage, onion, carrot ..	90	+	+ + +
Desiccated	10 to 15	+	0
Pickled, *e.g.*, cabbage			0
Fruit Juice—			
Fresh, *e.g.*, orange and lemon.. ..	90		+ + +
Lime Juice—			
Preserved (Army sample)			0
Eggs—			
Fresh	70	+ +	
Desiccated	6	+ +	0
Meat—			
Fresh	70	+	+
Tinned		0	0
Milk—			
Cow's (fresh)	87	0	Very slight
Yeast—			
Pressed, autolysed		+ + +	
Extract, marmite	30	+ + +	0

* 0 = no protection ; + = some protection ; + + = protection ;
+ + + = good protection.

The following are the chief points in this summary :—

Cereals and Pulses.—When all constituents of the grain are included, the cereals afford satisfactory protection against beri-beri, but none against scurvy. If the bran and germ (embryo) are removed in milling, as is the case with white (wheaten) flour or polished rice, no protection is afforded against beri-beri. Pulses are also a valuable source of anti-beri-beri vitamine. In the dry condition they, too, are useless for the prevention of scurvy.

If, however, the pulses (or cereals) are allowed to germinate, Fürst has shown that the anti-scorbutic principle makes its appearance. This discovery has been confirmed by Miss Chick

and her co-workers in the case of dry green peas, and they recommend germinated peas and lentils as a valuable and convenient means of preventing scurvy in the absence of fresh fruit and vegetables.

Vegetables and Fruit.—Cabbage and onion are about equally useful for the prevention of scurvy; carrot is less valuable. The great resistance of the onion to adverse conditions during transport and its notable value as a culinary adjunct mark it out as being specially suited to the needs of troops. Potatoes, while less rich than the above vegetables, have also an appreciable content of anti-scorbutic vitamine. Desiccated vegetables were found almost useless for the prevention of experimental scurvy, even when they were dried at low temperatures (30° to 37° C.). Dried vegetables were found useless in the Hungarian scurvy epidemic in the early part of the eighteenth century,* and were tried with the same disappointing result during the American Civil War.†

Fresh fruit juices appear to be among the most valuable of the anti-scorbutic materials. There is, however, little experimental evidence as to their value when preserved. One sample of lime juice, from the army depôt, was found of no value. Holst and his colleagues, on the other hand, demonstrated distinct anti-scorbutic properties in samples, many months old, of lime juice purchased in retail shops in Christiania. There is strong belief in the value of lime juice in the Royal Navy, and after a study of old records of the navy and mercantile marine, it is impossible to escape the conviction that scurvy can be prevented by its use. The previous history and method of preparation of the sample alluded to above, which was submitted for examination, are, however, unknown. The question of lime juice is of great importance and the matter requires further investigation, especially with regard to the methods of preservation.

Meat.—In practical experience fresh meat has been found a valuable means of preventing human scurvy, if taken regularly and in fair quantity. Perhaps the best example of this is afforded by the history of polar exploration.‡ The expressed juice of raw meat is also considered to be a useful means of curing infantile scurvy. For the prevention of experimental guinea-pig scurvy, however, meat was found to be disappointing; very little, if any protection could be demonstrated. It must

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* Charpentier, *Etude sur le Scorbut.* Paris, 1871.

† "Medical History of the War of Rebellion," Washington.

‡ See Nansen, "Farthest North."

be remembered that guinea-pigs are animals highly susceptible to scurvy, and further that meat is an unnatural food for them. They would not eat it, and all experiments had to be made with the expressed juices.

Milk.—Cow's milk possesses very low anti-scorbutic value. A daily ration of 50 grm. was insufficient to protect guinea-pigs (300–400 grm. weight) from scurvy. Scurvy could, however, be prevented by an exclusive diet of milk. The great value of milk as an adjunct to diet was apparent even when heated to 120° C. for one hour to destroy the vitamines. The general condition of animals receiving a minimum amount of anti-scorbutic material could be enormously improved by the addition of a daily ration of heated milk, although the scurvy was not influenced. Therefore, while admitting that milk is of little importance for the prevention of beri-beri or scurvy, its inclusion in a diet, even when tinned and sterilized, would appear to be a valuable measure.

Yeast Extract.—Yeast extract, while possessing anti-beri-beri vitamine in high concentration, is devoid of anti-scorbutic properties. The experiments were made with marmite.

Germinated Pulses.—The following methods were recommended for the germination and cooking of pulses when used as a source of anti-scorbutic vitamine.

The pulses should be whole, not husked or split in the process of their preparation ; otherwise they will not remain alive and germination will not take place.

The peas or lentils should first be soaked in water for twenty-four hours, during which operation 100 per cent. water is absorbed and the germination process begins. At this stage the anti-scorbutic vitamine, absent in the dry seed, has already made its appearance, but the amount produced is greatly increased if the germination is continued for one or two days more. For this purpose the excess of water is poured off and the seeds allowed to remain damp with access of air. The experiments were made at a temperature of 50° to 60° F. ; in warm climates the time could probably be much reduced, twelve hours sufficing for soaking in water, and one day or less for the further germination.

The germinated pulses should then be cooked in the ordinary way. It is important that boiling should not be prolonged beyond the time required for rendering them soft to eat and palatable, having regard to the sensitiveness to high temperature of the anti-scorbutic principle. In practice, boiling for one to one and a half hours for peas and half an hour or less for lentils

should suffice. No change in flavour can be detected when the seeds have been previously allowed to germinate. Care should be taken that the germinated peas or lentils should be cooked at once and not allowed to dry. If dried the anti-scorbutic vitamine produced during the process of germination again suffers destruction.

On 27th October, 1917, Major E. W. W. Greig, I.M.S., in a communication to the Director of Medical Services, India, made the following observations: "Regarding the question of the thermo-stability of anti-scurvy vitamine, it is interesting to note in this connection the effect of acids on the protective bodies of scurvy. As already stated, lime juice vitamine stands boiling for one hour. Raspberry juice and sorrel juice are both acid and strongly anti-scorbutic and will stand a temperature of 110° C. for one hour without affecting the scurvy protective substances. By the addition of acid to cabbage and dandelion juice, the thermo-stability of the protective bodies is raised. By boiling cabbage in 0·5 per cent. citric acid water a strong extract of anti-scorbutic substance is obtained."

Major Greig therefore suggested that 0·5 per cent. citric acid be added to the water in which the germinated grains are cooked and, further, that the acid water in which the germinated grains were cooked should not be thrown away but consumed along with them for the reason given above. If this suggestion were adopted he considered that the thermo-stability of the anti-scurvy vitamines in the germinated grains would be increased, and the cooking for one to one and a half hours required to soften dhall would not materially affect them.

His communication was forwarded to the medical authorities at the War Office, who sent it to the Director of the Lister Institute, requesting that experiments might be made to test the value of Major Greig's suggestions. On 9th December, 1918, the Lister Institute submitted the following memorandum to the War Office:—

"*Memorandum containing results of Experimental work by Dr. E. Marion Delf in the Department of Experimental Pathology, Lister Institute, in order to ascertain the influence of a small concentration of Citric Acid* (0·5 *per cent.*) *upon the deterioration in anti-scorbutic value taking place during the cooking of germinated pulses and other vegetables.*

1. *Material and Methods employed.*—The experiments were carried out with two sets of material:—

(*a*) Fresh raw cabbage leaves.

(*b*) Germinated lentils.

Guinea-pigs were the animals selected for the tests, and the series of materials of which anti-scurvy value was determined were added in weighed daily rations to the "scurvy" diet of autoclaved milk (60 c.c.) and oats and bran

TABLE VI.

Anti-scorbutic Value of Cabbage and Germinated Lentils, Raw and Cooked with and without a small concentration of Citric Acid. Experiments with Guinea-pigs. The Diet consisted otherwise of Autoclaved (1 hour at 20° C.) Milk, 60 c.c., and Oats and Wheaten Bran ad libitum.

Experiment No.	Anti-scorbutic Material.	Dose.	Number of Animals.	Length of Experiment.	Result.	Degree of protection against Scurvy (0 = no protection + = some protection + + = protection).
		Grm.		Days.		
Control	None	0	4	34 to 40	Death from scurvy 34th to 40th day.	0
1	Raw cabbage	0·5	4	50 to 91	Scurvy symptoms; some degree of protection.	+
		1·5	5	90	Protection.	+ +
2	Raw cabbage, after heating in steam at 90° C. for 60 mins.	5·0	4	21 to 29	No protection; death from acute scurvy.	0
3	Raw cabbage, with sap acidified with citric acid.	1·5	4	90	Protection.	+ +
4	As in experiment 3, but heated in steam at 90° C. for 60 mins.	5·0	4	25 to 34	No protection; acute scurvy.	0
5	Germinated lentils, raw ..	10·0	4	90	Protection.	+ +
		5·0	4	51 to 90	Distinct protection in 2 cases out of 4.	+
		2·5	6	48 to 92	Scurvy in all cases; slight protection in 2 cases.	+
6	Germinated lentils cooked in boiling water for 15 mins. at 100° C.	12–15	5	52 to 91	3 out of 5 died of scurvy; 2 others showed evidence of protection.	+
7	As in experiment 6, but citric acid present to a concentration of 0·5 per cent.	12–15	4	30 to 90	2 out of 4 showed evidence of distinct protection.	+
	Raw carrot juice	10 c.c.	4	34 to 76	All animals developed scurvy.	+
		20 ,,	3	75 to 95	Fair health; signs of scurvy in one case.	+ +
	Cooked potato in steam at 100° C. for 30 mins.	17 gr.	1	47	Slight protection.	+
		20 gr.	3	73 to 92	Protection.	+ +
	Raw scarlet runner beans..	5 gr.	3	84 to 91	Distinct protection.	+
		10 gr.	1	86	Protection; no scurvy.	+ +

ad libitum. The details of the experiment are set out in Table VI (Experiments 1 to 7), in which results obtained with other vegetables are included for purposes of comparison.

2. *Raw Cabbage Leaves: Influence of Citric Acid.*—The anti-scorbutic value of raw cabbage is extremely high; it was found that a daily ration as small as 1·5 grm. when added to a diet of oats, bran, and autoclaved milk was adequate to protect guinea-pigs from scurvy for the period of the experiment (Experiment 1).

In order to ascertain whether citric acid itself has any deleterious effect when included in the diet of a guinea-pig, a series of experiments was made in which the raw cabbage was placed overnight with the cut ends in a 1 per cent. solution. The acid solution was drawn up in the veins, and should be detected in the tissues of the leaf by expressing the sap and testing with litmus paper. A daily ration of 1·5 grm. of this acidified cabbage was found to be equal to the same ration of untreated cabbage; in fact, the animals were on the whole heavier, and in better condition at the end of the three months' period of experiment (Experiments 1 and 3).

3. *Cooked Cabbage: Influence of Citric Acid.*—Feeding experiments were made with this acidified cabbage after heating for one hour at 90° C. (Experiment 4). The ration given was 5 grm. and its anti-scorbutic value was compared with that of a similar ration of untreated cabbage (Experiment 2), also heated for one hour at 90° C. Both sets of animals developed scurvy more quickly, if anything, upon the cooked acidified cabbage diet than upon the cooked untreated.

4. *Raw Germinated Lentils.*—Lentils were soaked in water for twenty-four hours and kept moist and allowed to germinate for two days at room temperature. A daily ration of 10 grm. prevented scurvy with certainty, 5 grm. afforded protection in half the number of animals observed, 2·5 grm. proved insufficient in every case (Experiment 5). The value of raw germinated lentils is inferior to cabbage, is about equal to that of raw green beans, such as scarlet runners, and is superior to that of carrots.

5. *Cooked Germinated Lentils with and without Citric Acid.*—After cooking in ordinary water for fifteen minutes at boiling point, a ration of 12–15 grm. afforded considerable protection in some cases, in others (3 cases out of 5) death from acute scurvy occurred (Experiment 6). The anti-scorbutic value of cooked germinated lentils appears to be of the same order as that of cooked potato.

When citric acid to a concentration of 0·5 per cent. was added to the water in which the germinated lentils were boiled, 2 animals out of 4 receiving a 12–15 grm. ration died from acute scurvy, while the remaining 2 which survived for the period of the experiment showed a condition distinctly more scorbutic than those of Experiment 6.

6. *Conclusion.*—The presence of a low concentration of citric acid, viz., 0·5 per cent., has little influence upon the deterioration in anti-scorbutic properties, which normally takes place during cooking of vegetables: the effect, if any, is to increase the destruction to a slight extent."

It has recently been shown experimentally that the anti-scorbutic accessory factor (vitamine) is sensitive to free alkali, even when present in low concentration.* The practice of adding sodium carbonate to pulses and other vegetables before or during cooking is therefore harmful and should always be avoided.

The substance of Miss Chick's and Miss Hume's report on the prevention of scurvy and the methods suggested for the germination and cooking of pulses were telegraphed to the

* Harden and Zilva, *Lancet*, 7th September, 1918.

Commander-in-Chief, Mesopotamia, early in March 1917. After May 1917, germinated dhall was used in outlying districts in Mesopotamia as a ration when fresh vegetables or fruit could not be supplied.

Lime Juice.—Colonel Willcox found that the lime juice issued in Mesopotamia up to the end of 1916 had no anti-scorbutic value and produced no beneficial effect on patients suffering from scurvy. It usually arrived in Mesopotamia after a long journey overseas and was probably six months or more old when issued. At Colonel Willcox's suggestion, in August 1916, lime juice was prepared in India from fresh limes, a small quantity of alcohol (5 per cent.) and salicylic acid (2 gr. to the pint) being added as a preservative. This juice was sent to Mesopotamia in special casks with the date of preparation marked on them, and gave better results; it was used in the treatment of patients suffering from scurvy as well as for issue to troops. After the occupation of Baghdad, lime juice was prepared from limes and bitter oranges obtained locally; it was issued to troops with as little delay as possible and had an undoubted value as an anti-scorbutic.

The results of the investigation of lime juice carried out at the Lister Institute up to July 1917 are given in Table VII.

TABLE VII.

Experiment I.—Crude Lime Juice (Ration of 5 c.c. daily).

Sample.	Probable Age.	Anti-scorbutic Value.
(1) From Firm A, February 1917 ..	Uncertain, over 6 months.	Nil.
(2) From Firm B, sample obtained April 1917.	Very old.	Traces.
(3) From Firm C, sample obtained May 1917.	6 to 7 months.	Distinct value, some protection.

Experiment II.—Manufactured Lime Juice, clear, filtered (Ration of 5 c.c. daily).

Sample.	Preservative.	Probable Age.	Anti-scorbutic Value.
(1) Army sample, received from Army Supply depot, November 1916.	14 per cent. rum.	Unknown	Nil.
(2) Navy sample, received from Deptford depot, March 1917.	,,	,	Nil.
(3) Same sample as (2) without addition of rum; this sample was mouldy, March 1917.	Nil.	,,	Trace.

In a third control experiment with fresh lemon juice, without preservative, there was protection from scurvy in a similar ration of 5 c.c. daily.

These results confirmed Colonel Willcox's observations. It seemed probable that the age of the juice is an important factor, and that there is an advantage in having the juice as fresh as possible, the anti-scorbutic principle being gradually dissipated with keeping. Enquiries from manufacturers showed that commercial samples of lime juice may be many months old. In the case of lime juice from Firm C, the limes are squeezed in Dominica, the sugar in the juice is then allowed to ferment and when the process is finished the juice is shipped to England. In the London factory the crude juice stands in vats until the heavy particles have subsided and the suspended matter has risen; the intermediate layer of clear fluid is then removed by a syphon or by taps inserted at different levels in the vat, and then clarified by filtration through paper pulp. This clear liquid does not keep and rum or other preservative is added. When spirit is added the Board of Trade requires the lime juice to be clear. Further experiments showed that there was no necessity for the lime juice to undergo fermentation before it could be shipped to this country. It was found that when the limes were crushed in a special machine between rollers and the juice passed through a large silver mesh to remove heavy particles of rind, etc., the essential oils present in the pulp prevented fermentation of the juice, so that it could be sent to England without the addition of rum or preservative. As there was no advantage, save an æsthetic one, in waiting for the crude juice to sediment in order to obtain a clear juice, the official specification was altered and juice containing the pulp accepted, preservative to the extent of not more than 0·02 per cent. of sulphur dioxide being permitted. By these changes it was possible to deliver lime juice to the troops within a few weeks of its preparation in Dominica.

A sample of crude lime juice, without preservative, received from the West Indies, rather more than two months old, was tested in the Lister Institute by Miss Chick, assisted by Miss R. Skelton and Miss D. Gardiner. Two samples of lime juice, one with and one without alcohol and salicylic acid, made according to Colonel Willcox's formula in India and about two months old, were also examined by the same observers, samples of fresh lime juice and fresh lemon juice, squeezed in the laboratory from imported fruit, and fresh cabbage being used for comparison. The results are given in Table VIII.

TABLE VIII.

Article of Diet.	Description of Anti-scorbutic. Employed.	Age of Sample at time of Test.	Daily Dose.	Result.	No. of Animals tested.
		Months.	c. c.		
Oats, bran *ad lib.*, autoclaved milk.	Crude Bombay lime juice.	2 to 3	5·0	Acute scurvy in all cases leading to death.	4
do. do.	do. do.	3 to 4	10·0	do. do.	3
do. do.	do. (preserved)	2 to 3	5·0	do. do.	4
do. do.	Dominica lime juice, crude, without preservative.	3 to 5	5·0	Good health, but signs of scurvy.	3
do. do.	Fresh lime juice ..	*0 to 2	2·5	Scurvy in all cases.	4
			5·0	Scurvy in 4 cases out of 6.	6
			10·0	No scurvy.	3
do. do.	Fresh lemon juice ..	*0 to 3	2·5	No scurvy. Good health in 3 cases; in 1 case animal died from other causes.	4
do. do.	Fresh cabbage ..	Quite fresh	2·5 grm	No scurvy; good health.	4

* Squeezed in laboratory, preserved in refrigerator.

The Bombay crude lime juice, even in a dose of 10 c.c., did not prevent the development of acute scurvy in all the guinea-pigs and led to death. The crude Dominica juice, given in a dose of 5 c.c., had distinct anti-scorbutic properties ; the animals remained in good health but had signs of scurvy. Five cubic centimetres of the fresh lime juice prepared in the laboratory gave no better results, but when 10 c.c. were given there were no signs of scurvy. The fresh lemon juice in a dose of 2·5 c.c. protected the animals completely.

From these experiments it would appear that for the prevention of scurvy fresh lemon juice is four times as effective as crude lime juice.

Lemon Juice.—On 5th October, 1918, Miss Chick submitted to the War Office a memorandum upon the anti-scorbutic value of the juice of lemons and limes, and the superiority of the former. In this memorandum the results mentioned above were repeated and further experiments in which lime juice, prepared in the laboratory from fresh limes from Dominica, and fresh lemon juice, also prepared in the laboratory, were compared as regards the prevention of scurvy in monkeys.

Two series of healthy monkeys were fed upon a generous diet, containing rice, wheat germ, sterilized milk, wheaten biscuit, and pea nuts, the anti-scorbutic element being provided solely by the ration of fruit juice given. To one series fresh lemon juice was given ; to the other an equal ration of fresh lime juice. The results were as follows : The three monkeys receiving lemon juice were all in good health after five to

seven months; of the six monkeys receiving lime juice, one had severe scurvy, two incipient scurvy, two died from dysentery (one of which showed incipient scurvy), and one from an unknown cause.

With the object of obtaining corroborative evidence of the superiority of lemon juice from naval and arctic records, Mrs. Henderson Smith, at Miss Chick's request, made an investigation into the history of "lime juice" in the navy. Her enquiry has shown that until the middle of the nineteenth century the term "lime juice" was used to describe the juice of lemons from the Mediterranean districts, and that the regular supply of the juice of limes from the West Indies for the navy and mercantile marine was not arranged until after that period. The wonderful disappearance of scurvy in the navy which followed the compulsory issue of lime juice at the beginning of the nineteenth century must therefore be ascribed to the juice of lemons.

A striking instance is afforded by the experience of the arctic relief ships sent in search of Sir John Franklin, 1850–1854. The crews of those ships which were supplied with lemon juice of good quality, notably the "Investigator," commanded by Captain McClure, showed remarkable freedom from scurvy over long periods of time, notwithstanding great privation. The result was otherwise in the case of two ships, the "Alert" and the "Discovery," commanded by Captain Nares, which sailed from England in 1875 in an attempt to reach the North Pole. The equipment and dietary of this expedition were in every way superior to that of the former, but to the dismay of all concerned serious scurvy broke out at the end of the first winter spent in the arctic regions. The Commission of Enquiry, appointed by the Admiralty in 1876, were unable to find any satisfactory explanation of the disaster, but omitted to take any cognizance of the fact that the "lime juice" provided in 1875 was the preserved juice of West Indian limes, whereas in the fifties it had been the juice of Mediterranean lemons. There appears to be no doubt that in this fact lies the cause of the hitherto unexplained disaster.

In view of the greater efficiency of lemon juice in the prevention of scurvy it appeared desirable to replace lime juice by lemon juice as a general issue to troops operating under conditions where a sufficient supply of fresh vegetables and fruits could not be obtained. Enquiries were made, and it was ascertained that lemon juice such as Miss Chick had used in her experiments could not be obtained in the trade. A

conference was then held at the War Office, when it was stated that the best lemons came from Sicily, but if the lemons were treated in the same manner as the limes, in accordance with the new specification, it would be necessary to add a preservative to the juice before it could be shipped to this country. It was agreed that sulphur dioxide to the extent of 0·06 per cent. might be used, and a member of the firm which had been supplying lemon juice was sent to Sicily to superintend the manufacture of the lemon juice on the lines suggested. A good sample of the lemon juice arrived in England towards the end of 1919. It was examined in the Royal Army Medical College and found to contain volatile oil 0·10 per cent., suspended matter 0·25 per cent. and sulphur dioxide to the extent of 0·07 per cent. It was then tested at the Lister Institute and the results obtained were quite satisfactory; it was reputed to be "of excellent quality from an anti-scorbutic standpoint, and only slightly inferior to fresh juice."

BIBLIOGRAPHY.

Blane	Diseases of Seamen	London, 1789. Ed. 2.
,, ...	Progressive Improvement in the Health of the Royal Navy at the end of the Eighteenth Century, etc.	London, 1830.
Budd	Scurvy..	Tweedie's System of Practical Medicine, Lond., 1840, Vol. v.
Charpentier ..	Étude sur le scorbut.. ..	Paris, 1871.
Chick and Delf ..	The Antiscorbutic Value of Dry and Germinated Seeds.	Biochemical Jl., 1919, Vol. xiii, p. 199.
Chick and Hume ..	The Distribution among Food-stuffs, especially those suitable for the rationing of Armies, of the Substances required for the Prevention of Beri-Beri and Scurvy.	Trans. Soc. Trop. Med. and Hyg., 1917, Vol. x, p. 141.
Chick, Hume and Skelton.	The Antiscorbutic Value of Cow's Milk.	Biochemical Jl., 1918, Vol. xii, p. 131.
,, ,,	An Estimate of the Antiscorbutic Value of Milk in Infant Feeding.	Lancet, 1918, Vol. i, p. 1.
Chick, Hume, Skelton and Henderson Smith.	The Relative Content of Antiscorbutic Principle in Limes and Lemons, together with some new Facts and some old Observations concerning the Value of "Lime-juice" in the Prevention of Scurvy.	*Ibid.*, Vol. ii, p. 735.
Cooper	On the Protective and Curative Properties of certain Foodstuffs against Polyneuritis induced in Birds by a Diet of Polished Rice.	Jl. of Hygiene, 1912, Vol. xii, p. 436.

BIBLIOGRAPHY—*cont.*

Cooper	*Ibid.*, Part II	*Ibid.*, 1914, Vol. xiv, p. 12.
"	The Curative Action of Autolyzed Yeast against Avian Polyneuritis.	Biochemical Jl., 1914, Vol. viii, p. 250.
Curran	Observations on Scurvy, etc.	Dublin Quart. Jl. Med. Sci., 1847, Vol. iv, p. 83.
Delf and Skelton ..	The Effect of Drying on the Antiscorbutic and Growth-promoting Properties of Cabbage.	Biochemical Jl., 1918, Vol. xii, p. 448.
Delf and Tozer ..	The Antiscorbutic and Growth-promoting Properties of Raw and Heated Cabbage.	Biochemical Jl., 1918, Vol. xii, p. 416.
Ejkman	Ueber Ernährungspolyneuritis.	Arch. f. Hygiene, 1906, Vol. lviii, p. 150.
Fraser and Stanton	An Enquiry concerning the Ætiology of Beri-Beri.	Lancet, 1909, Vol. i, p. 451.
Funk	The Ætiology of the Deficiency Diseases.	Jl. State Med., 1912, Vol. xx, p. 341.
"	Ueber die physiologische Bedeutung gewisser bisher unbekannter Nahrungsbestandteile, der Vitamine.	Ergebnisse der Physiologie, L. Asher and K. Spiro., 1913, Vol. xiii, pp. 126–205 and 547–548.
Fürst	Weitere Beiträge zur Aetiologie des experimentellen Skorbuts des Meerschweinchens.	Zeitschrift für Hyg., 1912, Vol. lxxii, p. 121.
Greig	On the Substances protecting against Deficiency Diseases.	Indian Med. Gazette, 1913, Vol. lviii, p. 158.
Grijns	Ueber Polyneuritis gallinarum	Geneesk. Tijdsche v. Ned. Ind., 1901, p. 1.
Henderson Smith ..	A Historical Inquiry into the Efficacy of Lime-juice for the Prevention and Cure of Scurvy.	Jl. of R.A.M.C., 1919, Vol. xxxii, p. 93.
Holst	Experimental Studies relating to "ship Beri-Beri" and Scurvy. I. Introduction.	Jl. of Hygiene, 1907, Vol. vii, p. 619.
Holst and Frölich ..	*Ibid.* II. On the Ætiology of Scurvy.	*Ibid.*, p. 634.
" " ..	Ueber experimentellen Skorbut. Ein Beitrag zur Lehre von dem Einfluss einer einseitigen Nahrung.	Zeitschrift für Hyg., 1912, Vol. lxxii, pp. 1–120.
Schaumann.. ..	Die Aetiologie der Beriberi unter Berücksichtigung des gesamten Phosphorstoffwechsels.	Beihefte 8 z. Arch. f. Schiffs und Tropenhygiene, 1910, Vol. xiv, p. 325.
Simpson and Edie ..	On the Relation of the Organic Phosphorus Content of various Diets to Diseases of Nutrition, particularly Beri-Beri.	Annals of Trop. Med. and Parasitology, 1911, Vol. v, p. 313.
Stevenson	Notes on the Ætiology of an Outbreak of Scurvy in North Russia with an Experiment in Test-dieting.	Jl. of R.A.M.C., 1920, Vol. xxxv, p. 218.

BIBLIOGRAPHY—*cont.*

Willcox	Beri-Beri—with special Reference to Prophylaxis and Treatment.	Jl. of R.A.M.C., 1916, Vol. xxvii, p. 191.
„	The Treatment and Management of Diseases due to Deficiency of Diet; Scurvy and Beri-Beri.	Br. Med. Jl., 1920, Vol. i, p. 73.
Official	Report of the Lords' Commissioners of the Admiralty upon the Outbreak of Scurvy in the Recent Arctic Expedition.	London, 1877.

CHAPTER IV.

ENERGY EXPENDITURE IN RELATION TO FOOD.

IN the section on the food of the soldier at home, reference is made to experimental work which was commenced in 1917 when the first shortage of food was experienced, as it was felt that it would probably be necessary to give soldiers preferential treatment over the civil population. In May 1918 the food situation became more critical and, as already stated, an attempt was made to assess the energy requirements of the soldier by indirect methods, namely, assessment of the work done, the calorie value of the ration in kind, the number of calories purchased with the cash allowance, the amount of money spent by soldiers in the purchase of food in the canteens, and the amount of food the men received from their homes. This assessment was completed in a few weeks and the results appeared to show that soldiers in training were not then receiving more food than the nature of their work demanded if they were to be properly trained and sent overseas in a fit condition to bear the rigours of active service. But in view of the feeling amongst the civil population at home, it was considered absolutely essential to have an estimation made, as soon as possible, of the actual food requirements of the soldier in training. It was necessary to have a scientific estimation of the food calories required (1) for the work performed during the period of training,. (2) for play, rest, and sleep, and (3) for the building of the body tissues. The investigation was entrusted to Lieut.-Colonel E. P. Cathcart and Captain J. B. Orr. These officers submitted a preliminary report early in 1918, which confirmed the results obtained by the indirect assessment already mentioned. A complete report of their work was submitted a few months later and was published by the War Office in 1919.

Energy Expenditure during Training.

The work detailed was not an academic research but an investigation undertaken to obtain a prompt reply to a definite practical question. Time was precious, as it was a period of intensive training when every man was urgently required. The average length of training for the adult recruit until he was sent overseas was only 14 weeks of 582 working hours, so that the work of the units could not be disturbed by having special parades. The investigations were carried out

in two separate training camps, the object being to get the actual expenditure of energy under real conditions, so that there was no special arrangement or setting for the experiments. The subject of experiment was exercised along with the squad of men to which he belonged, so that the training carried out was not exceptional in any way.

Although in the programme of training a certain number of hours is set aside for the particular exercise, say bayonet practice, the whole time is not a constant sequence of movement. The hours may be roughly divided up into three sections: (*a*) men actually doing bayonet training; (*b*) instructor demonstrating and trying individual men; (*c*) all standing easy. Accordingly, assessments were made of the time spent in each of these divisions of activity and samples of expired air were collected from the recruit in correspondence with the divisions of time. Eventually the system of collection was changed, as it was thought that by collecting the expired air during every alternate minute or two minutes over the greater part of the drill a better result would be obtained. As a matter of fact, as regards the end result, it was practically immaterial which method was adopted.

The method employed in the investigation was that of Douglas-Haldane, that is to say, the expired air was collected in the Douglas bag and the analyses were done by the large Haldane apparatus. The greatest trouble throughout the whole series of experiments was to get the breathing regular. Several blank experiments were made on each new subject to get him accustomed to the apparatus. Records were usually begun on the third day, by which time all abnormal respiration due to psychic causes had ceased.

In the calculation of the energy expenditure the oxygen figures and the Zuntz values were employed. The methods are given in full detail in a paper published by Lieut.-Colonel Cathcart in the *Journal of the Royal Army Medical Corps*, November 1918. In order to assess the mean values of the energy expenditure in any group of data, the mean value of all the experiments done was taken irrespective of the individual on whom they were carried out.

As the investigation was carried out under actual conditions of training no two experiments, even in what are nominally the same drills, were replicas of one another. All that could be done was to obtain an average result of the amount of energy expended in performing any given type of drill or piece of work. As the amount of movement and the types of

movement studied were very few, it is reasonably certain that the average figures obtained are a close approximation to the actual value for the whole period of training. Other factors that produced variations in the results recorded for the same item of training were the influence of terrain and weather. Some drills were carried out on slippery parade grounds, others on rough hill ground, others on the public roads. The training went on in all kinds of weather except during heavy rain. At times the wind must have profoundly modified the result obtained. It is obvious that experiments carried out under these changing but always natural conditions gave a truer picture of the real energy expenditure of the soldier in training than if the men had been specially selected and segregated and the work carried on by means of special parades in the drill-hall.

The subjects of the experiments numbered sixteen; of these four were officers and twelve other ranks.

The scheme of training followed out was that in vogue during the greater part of 1918. There were two courses of training, one for adult and the other for young recruits.* The various subjects did the work of the day of the unit to which they belonged, so that their training as soldiers was scarcely interfered with. For purposes of comparison and in order that the data might be readily available for use the results were stated in (1) output of energy per square metre surface area per hour and in (2) expenditure per average man. In agreement with the Report of the Food (War) Committee of the Royal Society the average man was taken to be the British Association figure of a man 5 ft. 7·4 in. (171 cm.) tall, weighing 145 lb. (66 kilos) naked, with a surface area of approximately 1·77 square metres.

In order to determine whether the subjects of the experiments could be called normal, a number of lying experiments in the post-absorptive state was made. The average value of all the experiments gave an expenditure of 37·8 calories per square metre per hour, a reasonable approximation to the standard or basal metabolism value as laid down by the American workers (39·7 calories). There was, however, a very considerable variation, not merely in the mean values of results on different individuals, but marked variation in different experiments on the same individual. Careful experiments showed that the variation was not due to any fault in the

* Appendices I and IV of Army Council Instruction No. 100, of 1918.

method employed but was caused by the nature of the food consumed. Some soldiers partook of an evening meal rich in carbohydrates, others preferred meat or fatty food. A protein diet caused an abnormally high standard, 44·8 calories per square metre surface. A carbohydrate and fat diet gave abnormally low values, 35·6 and 35·1 calories per square metre surface respectively; an ordinary mixed diet resulted in a standard metabolism 40·9 calories per square metre surface.

It would have been best to take all the work in the post-absorptive condition, but this was impossible in the conditions under which the work was carried out. Fortunately the general nature and composition of the meals in the army varied very little from day to day. This standardization was rendered easy by the dietary tables issued by the Quartermaster-General's Department at the War Office. It was considered, therefore, that the mean value obtained from the various subjects could be used for deduction from the various work periods when the calculation of the individual pieces of work was made.

As the great majority of the movements associated with military training are carried out in the standing position, the expenditure of energy in this position was investigated. Standing "at ease" the increase over post-absorptive lying was 13·4 per cent., and "at attention" 33·8 per cent. A long series of observations was not made as the cost of the position assumed was necessarily included in the assessment of the values of the different exercises themselves.

A certain part of the training of the recruit is devoted to lectures when the recruit is either sitting on a bench or chair in a hut or out in the open. The expenditure of energy when sitting in the open is greater than when sitting on a more or less uncomfortable hard bench indoors. The mean value obtained, 48·8 calories per square metre per hour, showed an increase of 15·3 per cent. over the after-meals lying value.

The purely military elements of the energy expenditure were then investigated.

Squad, Section and Platoon Drill.—During the earlier stage of their military education recruits are trained in simple movements with and without arms. The mean value with no arms was 88·2 calories per square metre, with arms 140·8, and the mean value of all experiments was 130 calories per square metre per hour.

Company Drill.—The cost of this item differed very little from the previous exercise, and in view of this fact it was not considered essential to collect data from men doing battalion

drill. The average cost of company drill was 128·6 calories per square metre per hour.

Arms Drill.—This for the most part consists of the attainment of skill and accuracy in handling the rifle in various positions combined with instruction in aiming and firing. The energy expenditure, 80·5 calories per square metre per hour, was found to be remarkably uniform; probably due to the fact that no sets of muscles are severely taxed in performing the various movements.

Musketry.—This was investigated both at the large open range and at the miniature range. The average cost was not very heavy, 100 calories per square metre per hour. Far more costly than the actual firing and musketry practices was the marching to and from the range.

Bayonet Exercise.—A representative series of experiments was made so that a general average might be struck. It is an exercise in which the muscles are kept either in a state of tension or in active movement. Training had a great effect in cutting down energy expenditure by reducing useless movements. The mean value of all experiments was 121·4 calories per square metre per hour.

Assault.—This exercise, which is a comparatively rare item except towards the very end of training, is without doubt the most tiring excercise the recruit is called upon to perform. Great difficulty was experienced in arriving at a just estimate of the expenditure, as even the very best trained man, if a full assault course is carried out, rarely finishes except "out of breath." The mean value of all experiments was 216·1 calories per square metre per hour.

Physical Exercises.—Of all exercises carried out these are the best systematized and the best ordered. There is an excellent combination of fixed and more or less formal movement with free and voluntary movement in the form of games, with periods of instruction by the teacher and periods of rest by the recruit. The energy output is not excessive; the average cost was only 141·5 calories per square metre per hour.

Bombing.—In this form of training the only really hard physical work is the throwing of the Mills' bomb, weighing 1 lb. 7 oz., and even when trained each recruit does not throw more than fifteen in the hour. The average of all experiments was only 95·8 calories per square metre per hour.

Lewis Gun.—Apart from the moving around of the comparatively heavy gun weighing 26 lb. the energy expenditure involved in this relatively stationary type of training is small.

The average cost for this form of training was only 53 calories per square metre per hour.

Anti-gas Drill.—In the early stages of the drill the soldier is merely trained in the rapid adjustment of his protective appliance; in the later stages the item anti-gas drill might include the most varied forms of training, the only difference from the normal being that it is carried out with rather more difficulty, the man being hampered by his respirator. The average value was found to be the low one of 81·8 calories per square metre per hour.

Entrenching and Field Operations.—The work of entrenching in all kinds of ground is simply the expenditure of energy in hard navvy work using ordinary tools. Under field work is included a large variety of items of different kinds, methods of advancing, patrols, outposts, use of cover, simple field engineering, etc. The demands made by these different forms of training differed quite definitely, but it was thought that 187·2 calories for entrenching and 186·5 calories for field work represented the average of the energy output involved.

Extended Order Drill.—This consists in advancing over varying country, training the soldier in all the methods of closing with an enemy, the building up of a dominating firing line, and eventually the attack with the bayonet. The average value was high, 173·6 calories per square metre per hour.

Rapid Wiring.—This is one of the items of field training, but as it was difficult to incorporate this work in the ordinary field work experiments a few special observations were made. The average was 143·4 calories per square metre per hour.

Night Operations.—Only one observation was made, as apart from the fact that the work is carried out in the dark, it differs little, beyond the slowing due to lack of visibility, from ordinary day work. The expenditure of energy was found to be 101·2 calories per square metre per hour.

Guard and Sentry Drill.—There is no real difference between the movements performed during guard and sentry work generally and other forms of drill with arms. The cost was 102·3 calories per square metre per hour.

Kit Inspection.—This is not a mere display of the man's effects; there is a certain amount of routine, standing at attention, etc. The energy expenditure was found to be 73·6 calories per square metre per hour.

Fatigues.—The average figure obtained, 136·2 calories per square metre per hour, was thought to understate the cost of this class of work.

Marching.—This is the most costly item in the daily expenditure and, at the same time, the form of energy output which is most important from the military standpoint. The Manual of Infantry Training states that " the power of undertaking long and rapid marches without loss of numbers and energy is one of the chief factors of success in war." Military marching must not be confused with ordinary walking, where the length of the pace is regulated by the individual's choice, where the terrain covered is selected, and the duration of the length of movement and of halt may be varied at will. In military marching the pace is set and rigidly adhered to even when marching at ease, the terrain is subject to the military exigencies of the moment, and the length of march is regulated in like manner. In ordinary training the march rate is calculated to be at the average rate of 98 yards per minute, and the carriage of the soldier's body is also determined for him. The men, even when marching at ease, never march as they would in civil life. They may move their arms, loosen their clothing and equipment, but they do not break step or lose their dressing. Hence the expenditure of energy in military marching is much greater than in civilian walking.

The first set of experiments was done (*a*) in drill order; (*b*) in battle or fighting order; (*c*) with full equipment. The loads to be added to the body-weight were (*a*) 33 lb. 12 oz. or 15·3 kilos; (*b*) 45 lb. or 20·5 kilos; (*c*) 55 lb. or 25 kilos.

The percentage of weight of load carried to body-weight in the case of the average man, weighing 66 kilos, was in (*a*) 23·3, in (*b*) 31·1, and in (*c*) 37·9. As regards the rate of marching, the standard march of 100 yards per minute was adhered to throughout and was mainly carried out on a comparatively level and smooth stretch of road about 400 yards in length. As mean values, the average of all the experiments, either post-absorptive or after meals, marching at ease or at attention, was taken because the figures were considered on the whole to approximate most closely to the actual conditions of field training. The mean of all the experiments in drill order was 179·9 calories per square metre per hour, in battle order 214·2 calories per square metre per hour, and with full equipment 232·8 calories per square metre per hour.

When the values which were obtained for the output of energy by the various subjects with varying load are converted into values for the average man weighing 66 kilos, the cost of one horizontal kilogrammetre, *i.e.*, the cost of moving 1 kilo

through 1 metre on a level surface, can be worked out. This was done, and the cost in gramme calories per horizontal kilogrammetre was in the case of (*a*) drill order, 0·543, (*b*) fighting or battle order, 0·638, (*c*) full equipment, 0·672.

Benedict and Murschhauser, as the result of their work, came to the conclusion that " in general when the rate of walking does not exceed 80 to 90 metres per minute the values lie between 0·3 and 0·7 gramme calories, with a distinct tendency for them to approach 0·55 gramme calories," a result which is in satisfactory agreement with that obtained from the observations on soldiers.

The increased cost of the movement per horizontal kilogrammetre was quite marked when the load exceeded one-third of the body-weight. The percentage difference between drill order and fighting order was 17·5 per cent. The cost per unit of work was also found to rise steadily with the velocity at which the marching was carried out from 0·52 gramme calorie per horizontal kilogrammetre for the 11 kilo load at the slow march (57 metres) to 0·85 gramme calorie for doubling ; from 0·45 gramme calorie with the 16 kilo load at slow march to 0·81 gramme calorie for doubling ; from 0·49 gramme calorie with the 21 kilo load at slow march to 0·83 gramme calorie for doubling, and finally from 0·48 gramme calorie with the 26 kilo load at slow march to 0·72 gramme calorie per horizontal kilogrammetre for the rifle march at 109·7 metres per minute. The fact that there is a rise in cost due to increase of velocity has long been known. Zuntz and Schumburg in their calculations used the figure 0·0023 calorie per kilo per metre for each metre increase in velocity between 60 and 100 metres velocity per minute ; but their observations were few in number and they only tested two subjects and adopted the value 0·0023 which was obtained for one subject though the other gave a value of 0·0048.

In a series of observations which were carried out in testing different forms of equipment where the load was constant, Cathcart, Lothian and Greenwood found that marching much below the rate of 90 yards a minute is much more expensive than marching at any rate beyond 90 up to 130 yards per minute. It cost nearly 10 per cent. more calories to cover 100 yards at 60 yards per minute than at 90 yards per minute. The most economical rate of marching was at 88·38 yards per minute. When the influence of load was studied it was found that the cost in gramme calories per metre per hour was markedly increased with increasing load.

A number of observations was made on men marching in column and it was found more costly to march at the rear than in front.

A few experiments were carried out on the distribution of the load; the figures obtained seemed to show that very considerable latitude might be allowed without materially influencing the expenditure. The pack was carried as high on the shoulders as possible; well down on the buttocks; and about the middle of the back. Most of the Continental armies carry the pack higher than is the practice in the British army and as a result there is a tendency when marching to develop a forward stoop of the shoulders which necessitates a constant hitching of the load. The figures showed that the high position slightly reduced the expenditure, but unfortunately it is associated with the stooping posture or else to keep the load in position the adjusting straps and belt are drawn tight. The adoption of either or both of these devices leads to unnatural breathing which sooner or later tells on the soldier's efficiency, more especially if he be constrained to keep in formation and march in a definite fashion at a definite pace. On the whole it may be said that the normal position of the pack does not cause any abnormal expenditure.

The following table summarizes the energy expenditure in the various types of training.

TABLE I.

Energy Expenditure in Calories per Square Metre per Hour and Calories for Average Man (1·77 Square Metres) per Hour for the various items of Training.

	Calories per sq. metre.	Calories average man.
Lying post-absorptive	37·8	66·9
Lying after meals	42·3	74·9
Standing at ease	42·9	75·9
Standing at attention	50·6	89·6
Sitting (lectures)	48·6	86·4
Marching, drill order	179·9	318·5
Marching, battle order	214·2	379·1
Marching, full equipment	232·8	412·6
Squad, section or platoon drill, with arms	130·6	230·1
Squad, section or platoon drill, without arms	88·2	156·1
Company drill	128·6	227·6
Entrenching	187·2	331·3
Assault	216·1	382·5
Bayonet exercise	121·4	214·9
Physical exercise	141·5	250·5
Bombing	95·8	169·6

	Calories per sq. metre.	Calories average man.
Rifle bombing	111·2	196·8
Musketry	100·0	177·8
Anti-gas	81·8	144·8
Guard and sentry drill	102·3	181·1
Arms drill	80·5	142·5
Night operations	101·2	179·1
Rapid wiring	143·4	253·8
Extended order	173·6	307·2
Field work	186·5	330·1
Route marching	258·4	457·4
Fatigues	136·2	241·1
Kit inspection	73·6	130·3
Lewis gun	53·0	93·8

The approximate daily expenditure of energy during the fourteen weeks of training for adult recruits and for the twenty-four weeks of training for young recruits is summarized in the following table :—

TABLE II.

Approximate Daily Expenditure of Energy.

Adult Recruits' Course.		Young Recruits' Course.	
	Calories.		Calories.
3rd week	1,035	1st fortnight	721
4th „	1,167	2nd „	992
5th „	1,367	3rd „	1,220
6th „	1,415	4th „	1,285
7th „	1,376	5th „	1,293
8th „	1,592	6th „	1,312
9th „	1,418	7th „	1,458
10th „	1,819	8th „	1,489
11th „	1,698	9th „	1,528
12th „	1,820	10th „	1,506
13th „	1,757	11th „	1,499
14th „	1,875	12th „	1,603

In the adult recruits' course the data for the first two weeks are omitted as inoculation and vaccination were then carried out and the actual work done was small.

The following table gives two examples from each of the programmes of weekly work as detailed for adult and young recruits. An early and a late period of training in each case was selected so that some idea might be obtained of the nature of the work which the recruit in training was called upon to perform.

TABLE III.

Adult Recruits' Course.

3rd week.	Hours.	Cals.	10th week.	Hours.	Cals.
Physical training..	4	1,002·0	Physical training ..	6	1,503·0
Marching	2	636·0	*Bayonet exercise ..	6	1,480·0
Bayonet exercise..	3	644·7	Drill (marching order)	6	1,380·0
Squad drill (no arms)	12	1,873·2	†Musketry	6	1,345·0
*Musketry	18	2,642·4	Anti-gas	1	144·8
†Lectures and kit inspection.	3	363·1	Rifle bombing ..	3	590·4
Anti-gas	1	144·8	Entrenching ..	6	1,987·8
			Field work .. } 12 {	5	1,650·5
			Route marching }	7	2,653·7
Per week ..		7,246·2	Per week ..		12,736·4
Per day ..		1,035·0	Per day ..		1,819·4

* Musketry = 12 hours' instruction plus 6 hours' lectures.
† 2 hours' lectures, 1 hour inspection.

* Includes complete assault course 6 times.
† 4 hours' actual musketry, 2 hours' march to and from range.

Young Recruits' Course.

3rd fortnight.	Hours.	Cals.	10th fortnight.	Hours.	Cals.
Physical training..	10	2,505·0	Physical training ..	10	2,505·0
Bayonet training..	6	1,289·4	Bayonet training ..	6	1,289·4
Squad drill ..	20	4,602·0	*Drill .. .. }	12	2,609·4
*Musketry (miniature range).	20	4,247·5	†Musketry .. .. }		
Interior economy	3	300·0	Interior economy ..	2	200·0
Night work ..	3	537·3	Field work .. .. }	28	9,262·0
Guards	3	543·3	Field engineering .. }		
Anti-gas	2	289·6	Anti-gas	2	289·6
Special lectures ..	3	259·2	Bombing	6	1,017·6
†Organized games.. }	14	2,500·0	Route marching (Marching order)	2	824·0
‡School education.. }			Special lectures ..	2	172·8
			Organized games .. }	14	2,920·0
			School education .. }		
Per fortnight		17,073·3	Per fortnight		21,089·8
Per day ..		1,219·5	Per day ..		1,506·4

* Musketry = 15 hours' instruction, 5 hours' lectures.
† 8 hours' organized games at 300 calories per hour.
‡ 6 hours' school education = sitting calories.
In this particular period, as inoculation is done during 3rd fortnight, the expenditure has been lowered some 16 per cent.

* Drill 4 hours.
† Musketry, 8 hours (6 hours' musketry, 2 hours' marching).

In order to obtain the average expenditure for calculating the food requirements of a very large body of troops with a large number of individuals in all stages of training it was necessary that all the weeks of training should be considered. Accordingly when the figures given in Table II are averaged it is found that the daily expenditure under the scheme outlined in the adult recruits' course is approximately 1,528 calories, or 235 calories per hour, and in that of the young recruit 1,326, or 228 calories per hour. These figures give as the average weekly expenditure in training of adult recruits 10,810 calories and of young recruits 9,576 calories. It is to be noted that in making these calculations, instead of adhering to the actual 5½ days' training week, the expenditure was spread over the whole 7 days of the week. This perhaps gives figures slightly too low, as such extra items as church parades, items which are not put down in the scheme of training, but which lead to the expenditure of energy, were not considered.

Having obtained an accurate assessment of the expenditure of energy during forty-six hours (adult recruits) or forty-two hours (young recruits) of the 168-hour week, the problem still to be solved was the expenditure during the remaining 122 or 168 hours. As regards the time spent in the various phases of non-military activity, the average time spent in sleep per day was taken as 8 hours, or 56 hours per week; the remaining 66 or 70 hours were allocated as follows:—

Meals at 3 hours per day	21	hours	per week.
Cleaning equipment, washing, dressing, etc., at 1 hour per day	7	,,	,,
Fatigues	2	,,	,,
Free time	36–40	,,	,,

The assessment of the energy output involved in these various items was then considered.

Sleep.—The main assessment for sleep is the basal metabolism, namely, for the average man 66·9 calories. But in view of the fact that owing to hard beds, cold rooms and covering of very moderate weight the output of energy is greater than in the post-absorptive state it was considered that the basal output should be increased by at least 3 per cent. The expenditure then became 69 calories per hour, *i.e.*, 3,864 calories per week for the fifty-six hours spent in sleep.

Meals.—In estimating this item it was necessary to take into consideration not merely the heightened metabolism due to the ingestion of food, an average of increment of 16 per cent. according to Benedict and Murschhauser, and the mechanical

factors involved in consumption, estimated by Benedict and Carpenter from the mere movements of the jaws in chewing as an increase in the metabolism of 17 per cent., but also the discomfort, hard seats, etc., associated with the taking of food. In view of these facts the sitting metabolism was increased by 25 per cent.; and the total expenditure for the twenty-one hours per week was estimated to be 2,268 calories.

Cleaning of Equipment.—This was assessed at 50 per cent. increase on the sitting metabolism and the estimate gave 130 calories per hour, or 910 calories per week.

Fatigues.—It was estimated that the average soldier spent about two hours per week in the performance of fatigue duty of one kind or another. Direct measurements showed that the cost of fatigues varied very markedly. Taking the lowest figure observed, hut cleaning, at 207 calories per hour, the weekly output would be 414 calories, a very conservative estimate.

Free Time.—The assessment of the energy output was made as the result of careful observation of and enquiry about the habits of the recruit. As a result of these observations free time was divided into two phases: (1) resting phase, when he did little or nothing; (2) active phase, when he indulged in various forms of exercise. For the resting phase, an increase of 12 per cent. of the basal metabolism was given, which meant an output of 75 calories per hour. The allowance for the active phase was taken at 300 calories per hour, being based on the figures for walking without a load. It is certainly not excessive.

Table IV gives the data collected and applied for the whole week.

TABLE IV.

Adult Recruits. Weekly Energy Expenditure.

	Hours		Cals. per hour	Cals.	Percentage of Total Cals.
Sleep	56	hours at	69 cals. per hour	= 3,864	15·4
Meals	21	,,	108 ,, ,,	= 2,268	9·0
Cleaning	7	,,	130 ,, ,,	= 910	3·6
Fatigues	2	,,	207 ,, ,,	= 414	1·6
Free time :—					
(*a*) Resting phase ..	18	,,	75 ,, ,,	= 1,350	5·6
(*b*) Active phase ..	18	,,	300 ,, ,,	= 5,400	21·6
Drill	46	,,	235 ,, ,,	= 10,810	43·2
				25,016	

Daily expenditure of energy approximately 3,574 calories.

TABLE IV—*cont.*

Young Recruits. Weekly Energy Expenditure.

		Cals.	Percentage of Total Cals.
Sleep	56 hours at 69 cals. per hour =	3,864	16·3
Meals	21 ,, 108 ,, ,, =	2,268	9·6
Cleaning	7 ,, 130 ,, ,, =	910	3·9
Fatigues	2 ,, 207 ,, ,, =	414	1·7
Free time :—			
(*a*) Resting phase ..	24 ,, 75 ,, ,, =	1,800	7·6
(*b*) Active phase ..	16 ,, 300 ,, ,, =	4,800	20·4
Drill	42 ,, 228 ,, ,, =	9,576	40·5
		23,632	

Daily expenditure of energy approximately 3,376 calories.

These figures are believed to give on the whole a very fair estimate of the output of energy for the twenty-four-hour period. They were of inestimable value to the War Office during the critical shortage of food in England, as it was then possible to show by means of scientific data that the soldier in training was not being overfed as many were led to think. Indeed, when the figures for the caloric intake in the form of food were compared with the caloric output in the form of expenditure of energy it seemed that recruits were inadequately fed. Reference has already been made to this point and it has been fully considered by Lieut.-Colonel Cathcart and Captain Orr in their final report. Making allowances for the fact that the so-called hour's drill rarely exceeded forty-five to fifty minutes, and that the average surface area of the recruits studied by them was only 1·70 square metres, instead of 1·77 square metres, the surface area of the anthropometric standard man, Cathcart and Orr arrived at the general conclusion that the adult recruit's intake and output of energy probably just balanced and the young recruit obtained a sufficient surplus to permit of the increase of weight found. They, however, point out that while on theoretical economic grounds it may be admirable to balance the intake and output, yet in the case of the soldier a certain degree of surplus consumption is absolutely essential. The soldier in training for the battlefield should carry on his own person reserves in the form of fat and other material. The only method by which these internal reserves can be formed is by the giving of a definite surplus of food for long periods before the strain comes.

Energy Expenditure in Relation to the Equipment of the Soldier.

During the war, owing to the necessity of equipping a very large number of men, considerable difficulties were experienced in obtaining sufficient web material. Accordingly the web material of the braces, belt and pouches of the 1908 equipment was replaced by leather, the valise being still made up of the old material.

Very soon after this so-called 1914 equipment was issued, Major Johnston Stirling, R.A.M.C., when inspecting troops in training at Aldershot, noticed that the distribution of weights in the equipment was so imperfect as to necessitate the waist-belt being buckled very tightly in order to maintain the equipment in position. He suggested the addition of a supporting strap passing from a buckle in front and just above the ammunition pouch to the bottom of the valise on each side, and also the attachment of the valise to the belt. When these additions were made, Major Stirling found that even when the waist-belt was unbuckled the equipment remained in position, and when the belt was fastened loosely, the attachment of the valise to it enabled men to surmount obstacles and climb without any undue displacement of their equipment. His suggestions were referred to the War Office; but at first it was thought that the supporting strap might lead to constriction of the arm-pit; this, of course, was possible in a short stocky man if the attachment in front were made too high up. After some discussion it was decided to carry out some experiments on the lines of Major Stirling's suggestions, as it was realized that if the supporting straps could be made adjustable to the varying length of the body there should be no fear of constricting the vessels and muscles in the axilla. From the physiological point of view a perfect equipment should enable the soldier to carry his load without any interference with the movement of the chest, so that the increased respiratory exchange which accompanies increase of work may proceed in a normal manner, and without any undue pressure on any part of the body. From the military point of view it is essential that the adjusted load should not be disturbed during doubling or climbing of obstacles, and, when the belt is unbuckled, that the articles carried should be readily accessible and that the change from a marching to a fighting equipment should be readily made.

Whether an equipment is good or bad may be judged by :—

(*a*) Its appearance and movement during work.
(*b*) The feelings of the soldier carrying the load.
(*c*) The energy expenditure involved in carrying the load.

As regards (*a*) and (*b*) there may be a difference of opinion, but the estimation of the energy expenditure should prove an unfailing guide as to the best form of equipment and the best distribution of the load. Accordingly Cathcart and Lothian were asked to undertake a series of experiments on the soldier's equipment in relation to energy expenditure. They were supplied with the 1908 web equipment and the 1914 leather equipment, and were asked to give a definite reply to the following questions :—

(1) Is the present equipment unsatisfactory ? (2) Does the trouble which the average man has in carrying depend on the form of the equipment or on his mode of adjustment ? (3) Can any improvements of the present equipment in material, form, or mode of wear be suggested, or must a new pattern be sought ?

In the first place they made an attempt to sift the various complaints made by soldiers and to reduce them to some form of order. When this was done it was found that there were three outstanding grievances :—

(*a*) The pack did not lie comfortably on the back.
(*b*) The shoulders felt as if they were being drawn backwards.
(*c*) It was necessary to keep the belt uncomfortably tight, to the detriment of breathing.

Repeated tests on six officers, four of whom had been trained as infantry officers, showed clearly that the complaints had a basis of fact, particularly when the carrying of the pack was continued after the onset of fatigue. The irritating drag on the shoulders was the most marked of the three complaints.

A series of experiments on the energy involved in carrying the 1908 and 1914 equipments was then made. The Douglas-Haldane method already mentioned was employed. The experiments were all carried out after meals, but the time of the march after the last meal was varied from time to time in order to test the sense of comfort or otherwise in relation to food. In every instance the march periods were preceded by a lying period, so that the pre-work metabolism could be determined. The figure so obtained provided a base-line for calculating the actual energy cost of the carriage of the equipment. As a general rule the rate of march employed was

90 yards per minute (usually about 100 actual paces), but in order to develop differences between modifications of the equipment which were closely akin, control experiments were made at the rate of 60 yards per minute and 120 yards per minute. At the latter pace particularly differences scarcely obvious at the slower speeds were definitely developed. All the equipments carried weighed 50 lb. and were as evenly balanced as possible. The marches were carried out in a large well-lit cool laboratory measuring 30 yards from end to end. The floor was of wood and gave a firm grip for the feet. Indoor marching was selected in order that atmospheric influence might interfere as little as possible; the floor being always dry prevented all extraneous movements produced by balancing or slipping on a wet surface.

In the first place, repeated experiments were carried out with the 1908 and 1914 patterns in part to accustom the subject to the conditions of the experiment and in part to get definite information as regards the relative cost of carrying the two equipments. The following figures may be taken as typical:—

Equipment.	Pace in yards per minute.	Gross Cost in calories per minute.	Net Cost of carrying Equipment in calories per minute.
1908 web	90	5·75	4·50
1914 leather ..	90	5·55	4·30

The effect of the supporting strap suggested by Major Johnston Stirling was next studied. The average of seventy-seven experiments appeared to show that the introduction of the supporting strap definitely reduced the cost of carriage. The following average figures were obtained:—

Equipment.	Pace in yards per minute.	Net Cost of carrying in calories per minute.
1908 web	90	4·30
1914 leather	90	4·25
1908 web with special supporting strap.	90	4·00

Although the supporting strap reduced the expenditure of energy it did not lead to the abolition of the sense of drag on the shoulders. This question was then thoroughly studied. It was soon manifest from a consideration of anatomical details

of the bearing surface of the shoulder, that the happiest position for the shoulder straps had not been selected. In the ordinary type of equipment the shoulder strap lies well out on the shoulder and bears on the skin just above the head of the humerus. It was obvious that with the natural swing of the arms in marching the shoulder straps resting on the mobile deltoid and pectoral muscles must tend to move outwards. As a result a pull is set up which gives the feeling of a dragging back of the shoulders. Cathcart and Lothian, from a close study of the build of the equipment, came to the conclusion that the fault lay in the position of attachment of the shoulder straps to the pack. These straps normally are attached at a point some 1½ in. from the outer edge of the pack and of necessity must bear on the mobile deltoid. A pack was therefore constructed in which the two shoulder straps were attached to the pack so that their point of contact was in a line with the vertebral column of the bearer; further, these straps were set at such an angle that they came off straight from the pack and ran on to the soldier's shoulder so as to bear on the solid mass of relatively non-mobile muscle at the base of the neck. A further gain resulted, because when the shoulder strap was in this position and carried down to the ammunition pouches it cleared the heart on the left side and gave the bearer a large expanse of clear chest.

A series of tests was then carried out with equipment which contained both improvements—the supporting straps and new attachment of the shoulder straps. The following figures, the average of fifteen experiments, show that the gain was considerable.

Equipment.	Pace in yards per minute.	Net Cost of carrying in calories per minute.
With supporting straps and new attachment of shoulder straps.	90	3·74

This new equipment was thoroughly studied in various subjects at varying rates of marching, and it was found that it was not only comfortable to wear but also that it was very secure, and doubling could be done freely with the belt loose. The only objection was that when the pace was fast or when jumping or other more energetic measures were employed, the pack tended to swing outwards a little. The attachment of

the pack to the belt by means of a small strap attached below and in the centre of the pack not only led to a more comfortable pack but actually gave a further reduction in the cost of carriage. The average of twenty-one experiments gave at a pace of 90 yards per minute a net cost of carrying of 3·66 calories per minute.

In view of the fact that in the earliest tests of the original equipment it was found that the 1914 leather equipment was less costly to carry than the 1908 web, a series of experiments was carried out with a new pattern equipment with all improvements in which the shoulder straps of webbing were replaced by leather.

It was found that the substitution of the leather did lead to a further slight reduction, but it seemed questionable if the trifling advantage justified the construction of a mixed equipment of leather and web, especially as the quality of leather is so variable. As regards comfort there was nothing to choose between the two. The question arose whether the equipment would still be economical to carry when the webbing was stretched and worn. A set of equipment was made up to the new pattern from old web equipment with only a further 25 per cent. of life and tested against the standard type made up of new matèrial. In spite of the fact that the webbing was well worn, soft, and tended to rope, the figures obtained were in every respect as good as those with new material.

Finally, the new modified equipment was tested against an absolutely new pattern of equipment submitted by a private firm. The following figures give the relative cost of carriage of the two types :—

Equipment.	Pace in yards per minute.	Net Cost of carrying in calories per minute.
Private firm	90	3·80
New modified	90	3·66

It is evident then that there is a very considerable saving in energy expenditure between the 1908 or 1914 pattern equipment and the new pattern suggested, a saving of at least 0·74 calories per minute, or about 17 per cent. of the actual cost of carriage.

A saving of 0·74 calories per minute is equivalent to 44·4 calories per hour per man, and on an average working day,

even allowing at the minimum only two hours' carriage of equipment, means :—

88·8 calories saved per man per day.
88,800 ,, ,, battalion per day.
1,332,000 ,, ,, division (of 15,000 men) per day.

Cathcart and Lothian pointed out, therefore, that these figures represented calories saved, and if they are converted into terms of food saved they become even more striking, as the body does not yield 1 calorie of work for the ingestion of 1 calorie of energy in the form of food. A long series of experiments has shown that the human body under normal everyday conditions is only about 20 per cent. efficient, viz., for the production of 1 calorie of external work some 5 calories in the form of food must be taken. Hence the saving in terms of food calories would be :—

444·0 calories saved per man per day.
444,000 ,, ,, battalion per day.
6,660,000 ,, ,, division ,,

The saving in actual food would be even more striking, as it must be remembered that all the materials sent forward to feed men are not wholly utilizable ; there is a certain amount of waste and refuse which is generally put at 15 per cent. of the total amount. There is also a further loss to be taken into account, namely, the loss during transit in the field. If a very moderate allowance of 5 per cent. be made for this loss, the saving in food calories will amount to :—

533 calories per man per day.
533,000 ,, battalion per day.
8,000,000 ,, division ,,

In actual food these figures amount to a saving of :—

9 oz. of food per man per day.
562 lb. ,, battalion per day.
8,442 lb. ,, division ,,

It is not suggested that if the new pattern be adopted the food ration should be cut down accordingly ; the saving merely refers to the cost of work, but the fact that the new pattern equipment is infinitely more comfortable to carry is a factor of incalculable benefit when it comes to the physical question of moral. It is very obvious that the onset of fatigue will be postponed, and even in the case of fatigued men the new pattern is much less irksome than the old. There is a further possible advantage, namely, if it be considered advisable, it would be practicable to add two more ammunition pouches,

giving a total number of 180 cartridges, without unduly interfering, apart from the increased weight, either with the balance or the comfort of the equipment.

As regards comfort, the development of the various experimental equipments has shown an almost exact parallel between the reduction in energy cost and the increase in comfort. The new model is quite the most comfortable equipment yet worn. There is complete freedom of movement of the body and arms, absence of pressure over the heart or lungs, absence of constriction of the abdomen, and an excellent, well-balanced " set " to the body. The pack rides sufficiently far off the back to allow a ventilation space, and the ammunition pouches are so placed as to permit of the wearer lying down without discomfort or pressure. There is a certain firm rigidity which permits of rapid or up-and-down movement without shifting and swaying of the pack. There is also little or no tendency to stoop forward to support the back.

A few trials with the modified equipment were made with favourable reports by some infantry units stationed at Aldershot.

A further trial was made at Salisbury; complaints were made of pressure by the supporting strap. This is quite possible if it is not properly adjusted.

Energy Expenditure in Relation to the Load carried by the Soldier.

The question of the load carried by the soldier is one of paramount importance, as apart from the actual physical efficiency of the man it is the factor which governs the capacity of the soldier to reach his objective. As Colonel C. H. Melville well phrased it, " the soldier is an expensive specialist, and it is false economy to turn him into a baggage animal, which is a poor form of unskilled labour."

In common with all other nations, Great Britain has insisted on the fact that the power of undertaking long marches without loss of efficiency is one of the main objects of military training. The war, in its latest stages at least, again proved this to be a well-founded principle. But the war did more; in many instances, *e.g.*, when the final advance took place on the Western front, it showed that the majority of the troops could not advance at the rate required if they were called upon to carry the loads which were demanded of them in the days of more or less stationary warfare.

The general consensus of opinion has held that the maximum load to be carried, if it is not to impair the value of the soldier as a fighting unit, should not exceed approximately one-third of the body-weight. Unfortunately, for two reasons, during the greater part of the duration of the war such a weight was not, and probably in the majority of instances, and in the case of the infantry at least, could not, be adhered to. In the first place the physique of many of the men in the field was much below the standard demanded in peace-time. This did not merely apply to the muscular development of the men but also to the actual body-weight. In other words, there was a great lack of uniformity in the various individuals both as regards training and physique in the different units, but the equipment issued to the men was uniform and standardized.

In the second place, as the war progressed the load to be carried tended to increase steadily. This steady increase was not due to haphazard additions but was forced upon the army by the constantly changing conditions of warfare, entailing as it did a constant increase in the variety of equipment both offensive and defensive, the necessity of supplying as protection against climatic conditions special garments such as leather jerkins and fur coats, during the period of stationary warfare, and the increase in the weight carried by the soaking up of moisture and the accumulation of mud—a factor which had been practically ignored. Hence it happened that there were many instances in which the load carried far exceeded the approved maximum. It was not uncommon to find the soldier carrying a load 75 per cent. and more of his body-weight, although probably the average in infantry units was about 60 per cent. of the body-weight.

This figure of 60 per cent. is arrived at from practical observation and experiment. Cathcart and Orr noted that the average weight of the young soldiers sent overseas was about 60 kilos, and the weight of the load could be readily calculated. In the winter period at least it amounted to about 77·5 lb. (35·2 kilos), made up as follows :—

	lb.	oz.
Weight of kit and accoutrements	60	11¼
Extra shirt	1	1½
Extra pair of drawers	1	1
Extra socks		4¼
Second iron ration	2	6½
Fur coat	4	12
	70	4½
Or if leather jerkin (2 lb. 15 oz.) were issued in lieu of fur coat	68	7½

In addition to the above the following extras were carried :—

	lb.	oz.
Ground sheet	2	8
Box gas respirator	3	8
Gloves		4
Vest woollen	1	0
	7	4
This gives a total of—		
(1) With fur coat	77	8½
(2) With leather jerkin	75	11½

But the above items do not by any means exhaust the weight carried by the soldier. There are other small items such as a body-band weighing 11 oz., inner soles for ankle-boots, waterproof cap covers, and the personal belongings of very varying weight always carried by the soldier. And finally, although the above estimate may give a very fair approximation to the weight carried by the soldier in dry weather, in wet weather there was certainly a very definite although perhaps variable increase owing to the absorption of water by the clothes, mainly the great-coat, and the abundant overlay of mud. Careful estimations of the gain in weight of the clothing in wet weather were made in France and it was found that the weight of the great-coat when wet might be increased by about 20 lb. exclusive of any adherent mud, and that mud together with water on wet equipment, trousers, puttees, and boots adds at least an additional 14 lb. This brings the load which the soldier may have to carry to the extraordinary total of 114 lb., and this apart from any additional supplies such as extra ammunition, bombs, etc., which were by no means rare addenda. Even if the total load be taken at 114 lb. this would mean that the soldier might be called upon to carry about 87 per cent. of his body-weight. The difficulty did not end here, because the soldier so laden was compelled to move forward over country which at times was literally a sea of thick slippery mud offering a most precarious foothold which necessitated the expenditure of a great deal of energy in balancing the top-heavy load.

Cathcart and Orr in their investigation into the energy expenditure of the recruit in training dealt in some detail with several of the problems involved. They confirmed the observations that not only does the energy expenditure increase with increasing velocity of forward progression but that there is also a well-marked increase in energy output with increasing load. In a later incomplete series of experiments, which were carried out by Cathcart, Jameson and Dawson, sufficient

evidence was obtained to show that a load which forms approximately 40 per cent. of the body is the ideal at which to aim. Cathcart and Orr were unable to find that the disturbance of the balance of the equipment led to any great increase in the cost of marching. Their experiments, however, were carried out on a a firm floor which gave exceptionally good foothold, a condition which in warfare at least is much more uncommon. Lack of balance would obviously accentuate markedly the difficulties of marching on ground with an uncertain foothold and would lead to a definite rise in the energy cost.

The dangers of excessive loads are not confined to the fact that the energy expenditure is high and as a result the demand for food is greater, that fatigue is induced earlier, that the fighting quality of the soldier diminishes more rapidly and that finally there is a definite lowering in moral. Far-reaching pathological effects may be produced as the result of the carriage of excessive burdens. The vital capacity has been shown by Zuntz and Schumburg to be reduced about 9 per cent. with a load of 48 lb. and about 11 per cent. with a load of 59 lb. If the carriage of the abnormal load is persisted in, there may follow a very definite engorgement of the base of the lungs, emphysema, and increased cardiac and hepatic dullness.

Such a condition implies the existence of marked venous back-pressure which may result in renal congestion and subsequent impairment of renal function.

Under normal conditions the strain on the physique of the men was very severe in the march up to the trenches even although the troops had been adequately rested in "rest billets," but the evil effects were aggravated when the men, already fatigued both physically and mentally by duty in the trenches, were called upon to carry an excessive load for many miles frequently under adverse conditions as regards both road and weather, and with the atmosphere probably so saturated that the heat-regulating mechanism of the body was tried to the uttermost.

Little or nothing could be done to lighten the load during the course of the war. It is, however, a problem the solution of which must be faced. The whole question of the mode of carriage of the load will be largely dependent on the nature of the warfare which is anticipated—open or stationary. If it be open, it will in the real sense of the term be one of movement. If this be granted, then the words of von Moltke are as true to-day as when they were written, "from the standpoint of the higher strategy what we want is not a 'light battalion'

but a 'light army' . . . . a tactical victory is only decisive when it occurs at the strategically correct position, and that can only be attained by an army equally mobile in all respects . . . . an army which marches light will also manœuvre freely."

Whatever be the nature of the warfare, it is highly improbable that the equipment now on issue can be materially lightened by discarding any of the items included in the list. There are two possible solutions, either that more of the load be carried mechanically or that by improvements in material and design the present essentials be lightened. There will be immense difficulties in increasing transport, but some reduction might be obtained by attention to the second alternative. The present heavy great-coat with its capacity to absorb moisture might for example be discarded, and a heavy sweater and a waterproof of the poncho type substituted. This alteration would also get rid of the ground-sheet and allow of the adoption of a smaller and lighter pack.

CHAPTER V.

PRISONERS OF WAR.

SOME comprehension of the extent of the supervision necessarily undertaken in connection with the hygienic control of prisoners of war may be acquired by knowledge of the numbers and distribution of camps in which prisoners were maintained in the United Kingdom alone. In addition to 440 camps there were many agricultural groups, as well as migratory gangs, housed in summer in some situations under canvas. For these medical arrangements were made locally, sanitary constructions were installed, and systematic inspection maintained.

The following table gives the particulars of thirty-five of the main camps and hospitals.

TABLE I.

Situation.	Nature.	Date of Opening.	Prisoner Accommodation.
1. Dyffryn Aled ..	House	2. 9.14	90 Offs. 30 Srvts.
2. Holyport, Maidenhead.	House, huts, timber and asbestos.	14.10.14	500 ,, 160 ,,
3. Donington Hall, Derby.	Mansion house, huts and hospital.	2. 2.15	410 ,, 121 ,,
4. Colsterdale, Yorks.	Huts	15. 8.17	700 ,, 200 ,,
5. Sandhill Park ..	House, outhouses, huts.	26. 3.17	400
6. Kegworth, Derby	Buildings	2.10.16	800
7. Skipton, Yorks.	Huts	1. 1.18	552 ,, 160 ,,
8. Bevvis Mount, Southampton.	House	16. 9.14	85
9. Ripon	Huts	9.10.18	1,200 Men.
10. Ripon	Huts of brick, etc...	10.18	720 Offs. 216 ,,
11. Redmires, Sheffield.	Huts	31.10.18	650 ,, 156 ,,
12. Lofthouse Park, Sheffield.	Buildings and huts	10.14	874 ,, 250 ,,
13. Park Hall, Oswestry.	Huts and hospital ..	9. 4.18	10,000 Men.
14 Lewisham ..	Mansion house ..	23. 4.18	40 Offs. 10 ,,
15. Margate ..	House	20. 3.18	82 ,, 27 ,,
16. Ramsgate ..	House	2. 4.18	120 ,, 35 ,,
17. Southend ..	House	2. 3.18	40 ,, 10 ,,
18. Brocton, Staffs.	Huts and hospital ..	10. 4.17	7,000 Men
19. Bramley, Hants.	Huts, timber and brick.	26. 3.17	?

TABLE I—*cont.*

Situation.	Nature.	Date of Opening.	Prisoner Accommodation.
20. Catterick, Yorks.	Concrete huts	12. 4.17	4,000 Men.
21. Chepstow, Mon.	Concrete huts ..	1.12.17	4,000 ,,
22. Lancaster and Templemore.	Buildings and barracks.	8.14	4,000 ,,
23. Frongoch ..	Brick and stone buildings and huts.	15	1,800 ,,
24. Handforth ..	Brick buildings ..	22.10.14	3,000 ,,
25. Leigh, Lancs. ..	Factory buildings ..	28. 1.15	1,785 ,,
26. Pattishall ..	Huts	—	4,000 ,,
27. Stobs	Huts	22. 8.14	5,960 ,,
28. Shirley Rink, Southampton.	House	16. 9.14	1,000 ,,
29. Shrewsbury ..	Buildings and railway works.	—	500 ,,
30. Blanche Banques, Jersey.	Huts	12. 4.18	1,500 ,,
31. Oswestry ..	Huts	9.18	1,800 Offs. 450 Srvts.
32. Slough	Huts of timber, etc.	4.10.18	2,500 Men.
33. Feltham, Middlesex.	Institution building	14. 2.16	1,500 ,,
34. Alexandra Palace.	Building	5.15	3,337 ,,
35. War Hospital, Dartford.	Hospital	9. 9.15	1,242 ,,

From the wide range of situation of the camps and the numbers in each, great variety necessarily existed in the structures adapted for the housing of prisoners of war. Sites for new camps were selected for their general salubrity, convenience of access, porosity of soil, adaptability for sanitary installations, availability of water supply, and other hygienic requirements. Of the conditions necessary for a satisfactory camp, porosity of soil was the least easy of general attainment, and in rainy weather discomfort was complained of at many camps situated on clay soil. Meteorological conditions had to be tolerated, but in time the discomfort resulting from water-logged soil was overcome by various measures of linking up the camp units by roadways of timber, ash, breeze, or stone, according to the local material available. Camps were closed in localities where expenditure necessary to overcome unsatisfactory local conditions seemed unjustifiable.

Camps for officers and other ranks at a port suitable for the disembarkation of prisoners were among the first established on the outbreak of war. A large private house and a skating rink used for this purpose at Southampton had accommodation at first for 80 officers and 800 men respectively. They were

capable, in an emergency, of accommodating an additional 25 per cent. Camps of double the size would have been preferable, but this was precluded by local conditions.

A small camp was established in London for the reception, in special cases, of the crews of enemy aircraft, submarines, and so on, captured in this country or in the adjacent waters. They were drafted from this to one of the main camps.

The permanent camps were enclosed as a rule by two fences of barbed wire, 6 ft. high and 10 ft. apart, the space between them being filled with coils of loose barbed wire. At a distance of 10 ft. from the second fence was a plain wire fence 3 ft. high.

In camps of a semi-permanent nature, less elaborate precautions were taken.

Accommodation.

Many of the existing institutions were occupied, such as military camps, industrial works and factories, educational and other institutions, mansion houses, in country and in town, farm buildings, and so on. Hutments were of brick, timber, various materials, such as wattle and daub, or concrete. In the summer months, especially for migratory gangs, canvas tents were employed.

In existing buildings ventilation was of the usual character; in new hutments similar methods were adopted; but in extemporized and adapted buildings varied improvizations and remodelling had to be adopted to secure satisfactory ventilation.

Accommodation in general, except in isolated cases early in the war, was abundant, and overcrowding was unknown. In rare cases in simple huts in working camps a double-tier bunk system was in operation, with satisfactory results; but on hygienic grounds the system was not extended.

In camps for timber felling, which were often, especially in Scotland, situated in places far removed from habitations, it was as a rule necessary to construct buildings for occupation during the winter months from materials found on the spot. Buildings erected under these conditions sometimes took the form of the wattle-and-daub Kaffir hut, well thatched. The prisoners were soon expert in constructing these huts, which proved a great success. Sometimes simple huts were run up, with bunks in two tiers on either side of a central passage. This double-tier system was not adopted elsewhere on sanitary grounds, but no harm seems to have resulted from its use in these localities.

The water supply was everywhere assured, abundant and of known quality; new systems were installed where none existed. In smaller working camps and amongst migratory gangs the local well and stream supplies of the country people were used. No water-borne diseases have been recorded.

Every convenience was installed for washing and bathing, and open-air swimming baths were constructed wherever possible. In some situations, in the early days of the camps' existence, accommodation was limited, but no hardship of any duration was suffered.

The conventional methods for removal and disposal of refuse were employed, varying from the most modern and elaborate installations in institutions to the primitive arrangements of agricultural and rustic surroundings. No grievance or disease connected with sanitary conservancy has been recorded.

Arrangements had frequently to be made with local civil authorities and private property owners to facilitate the erection of sanitary installations. Objection was occasionally raised to sewage outfalls and incinerators on the score of nuisance, but these difficulties were readily overcome, and in some cases the installations ultimately proved of use to the neighbouring communities and were taken over by them.

Liaison in all these matters was maintained with the Local Government Board and the local authorities.

Employment and Exercise.

At all places, both for officers and men, ample arrangements for exercise were made. The employment of prisoners of war on works commenced in Great Britain in the spring of 1916. Beyond occasional complaints of certain work being too arduous, and requests for an enhanced dietary in certain occupations nothing but general satisfaction resulted from employment. In agriculture especially the employment of migratory gangs worked admirably, the assistance to farmers was useful, and the hygienic advantage to the prisoners was marked. The reports of the visiting deputies of the Embassies are unanimous in remarking on the vigour, contentment, and healthy appearance of prisoners, especially those employed in agriculture.

The detailed arrangements for the employment of prisoners of war in this country were as follows: Each working camp was affiliated to a "parent" camp, which was one of the permanent camps in the country. The "parent" acted as the channel of communication and kept a supervision over camps affiliated to it. The larger working camps were self-contained,

but the smaller, *i.e.*, those with an establishment of under 200, looked to the parent for accounting, clothing, etc. One of these parent camps had 164 working camps of various sizes affiliated to it. This procedure threw heavy work on the staffs of parent camps, notwithstanding that they were specially increased.

Prisoners were called on to work for the same number of hours as British workmen in the locality when engaged on the same kind of work. They were also required, if necessary, to march three miles (one hour's march) to and from the place of work. Any time required to reach or return from this place in excess of one hour was deducted from the hours of labour. In agreement with the German government, one rest-day a week was allowed. This was always a Sunday, except during the harvest. Men employed on farms or agriculture could be called on to tend livestock or produce under glass for not more than two hours on Sundays.

The gradual increase in the number of prisoners of war employed is shown in the following table, which gives the number in the last month of each quarter of 1917 and 1918 :—

1917 :	March ..	7,029				
	June ..	21,690				
	September	25,147				
	December	27,760,	of whom	1,782	were	civilians.
1918 :	March ..	33,889	„	2,159	„	„
	June ..	45,710	„	2,360	„	„
	September	62,106	„	2,573	„	„
	December	66,853	„	1,356	„	„

Many men had to be employed on work to which they were unaccustomed, and many of the professional and trading classes were totally unused to, and resented, manual labour of any kind. Every employer held that with the gradual reduction of the ration and the constantly decreasing supplies of food in canteens on which men could spend their earnings the output declined.

In April 1917, the Prisoners of War Employment Committee was requested by the War Office, at the instance of the Select Committee on National Expenditure, to investigate the methods of remuneration of prisoners of war and to make recommendations as to how the greatest output of work could be obtained in the United Kingdom and in France. The committee was strengthened for this purpose by additional members with special qualifications. They obtained evidence from all Government departments which employed prisoners and from private employers and contractors, as well as from the Directorate of Prisoners of War. They reported in the summer of 1918 that

"a heavy day's work could not be obtained from the prisoners without some supplement to their rations. The evidence on this subject was overwhelming, and all but unanimous. All agreed that no mere money inducement would suffice to obtain the maximum output so long as more food could not be procured. Money was of little value to the prisoners if they could not spend it on anything they wanted, and of all their desires it seemed certain that extra food was uppermost in their minds."

The scale of rations which obtained at that time was by no means generous, though it was all that could be provided, owing to scarcity in the country. The opinion of the committee, which was endorsed from many quarters, was undoubtedly sound, especially in the case of Germans, who are heavy feeders. They did not, however, recommend an increase of the ration, but that camp canteens should be stocked with food on which prisoners could spend their earnings; and that in the smaller camps, which had no canteens, opportunities for local purchase should be provided. Effect could not be given to the former, owing to insufficiency of supplies in the country and to strong objections raised by the public, and the latter could be carried out only to a very limited extent.

The conclusions reached by the British military authorities in France, as to the factors which influence output, are precisely similar to those which were arrived at in the United Kingdom. They may be summarized as follows:—

Supervision can be exercised only by skilled men for skilled work. Unless the prisoner of war non-commissioned officer was himself a skilled tradesman he was useless, except as a channel for the maintenance of discipline.

In other forms of labour the German non-commissioned officers, when supervised, were, as a rule, found to be most useful.

An increase of pay without the means of spending it, especially on food, will produce very little result.

An increase to the ration, which may be withheld from slack workers, is a direct incentive to steady work and increased output.

A weekly rest-day is productive of good work.

The Controller of Labour in France reported as follows:—

"The standard of comfort enjoyed by the prisoners in their compounds has a direct bearing upon their general efficiency, both mental and physical, and consequently is reflected in their output of work.

"A good company officer who takes a keen interest in the accommodation provided for his men, good cooking arrangements, baths, recreational facilities and so on, invariably secures the best results in the working efficiency of his company. The prisoners, if given the opportunity, are only too willing to work in their spare time in improving the comfort of their camps, and even in devastated areas can, in a very short time, erect most comfortable quarters from material salved in the neighbourhood of their camps.

"All this tends to efficiency of work generally, and is a convincing argument in favour of putting officers of initiative and experience in command of prisoners of war companies."

Such work as mail-bag, thermometer, and brush-making was carried on in parent camps by civilians or by combatants who were physically incapable of heavy labour.

A start was made with the manufacture of glass eyes, for which prisoners with the necessary skill were found. But as the only colouring obtainable was a vivid blue they were not generally popular and the work was discontinued.

Similar employment arrangements were made for prisoners of war in France, Italy, Macedonia, Egypt, Mesopotamia, and elsewhere, with good results as regards their health.

Medical Attendance.

Arrangements on a generous scale were made for medical attendance and sanitary supervision. The nature of the situation determined the camps where regimental medical officers could be in constant attendance, or civilian medical practitioners in part-time attendance and statutory visitation, or where in certain situations German medical officers could be employed. The usual regimental supervision by the responsible officers of the Home Commands was maintained, inspections by officers from the War Office were carried out and medical officers of the Swiss Legation were on the rota of visitation of that Embassy.

Dental treatment of prisoners of war was arranged for in an Army Council Instruction.*

The following note on the medical treatment of prisoners of war is given in the official report of the Directorate of Prisoners of War.

" A hospital was opened at Dartford in September 1915, solely for the treatment of combatant and civilian prisoners of war, in which proper precautions to prevent escape, to ensure the censorship of correspondence and the many other special conditions of a prisoners of war camp could be enforced. As all sick and wounded prisoners who were likely to require treatment for more than a few days were sent to this country from France as soon as they were fit to travel, it was soon necessary to extend this accommodation, and at the date of the armistice with Germany, seven hospitals with 8,800 beds were entirely set apart for the treatment of prisoners. In exceptional cases, men requiring treatment were sent to an ordinary military or civil hospital until fit to be moved to one of the assigned hospitals or to an internment camp.

* A.C.I. 656 of 1917.

"Necessary operations only were undertaken; others were postponed. Special arrangements were made for the observation of prisoners convalescent from typhoid fever or dysentery, and for those requiring prolonged treatment by massage, electricity or mechanical apparatus. Spectacles were supplied on payment. Medical records and a medical history sheet were kept for all prisoners treated in hospitals.

"In addition to these large hospitals, each camp had a hospital, with beds to the number of about 2 per cent. of the total accommodation, for the treatment of minor and urgent cases; but this percentage varied with the distance of the camp from a main hospital. In small working camps first-aid appliances were, as a rule, supplied, and recourse was had to the services of the local doctor.

"An insane civilian prisoner of war was removed to an ayslum in accordance with the laws of the country. If he had been a resident in this country before internment he was, if possible, transferred to the asylum of the district in which he had previously lived. If the patient's means were such as not to call for treatment at the public expense he could be sent, in consultation with the proper authorities, to some suitable institution. Insane combatant prisoners were transferred to specified hospitals. The question of the repatriation of the patient was taken up as soon as insanity had been established."

Prisoners of War Rations.

Much consideration was devoted by the Army Medical Department at the War Office in arranging suitable and, according to the exigencies of the times, just scales of rations for prisoners of war. In brief, they were so adjusted as to supply variety and calories ample for the condition of prisoners—civilian, officer, and soldier—and for the occupations on which they were employed. They were generous in the circumstances, and compared favourably with what was available for the public generally.

In the United Kingdom.—In August 1914 the following issues were authorized as a tentative measure: Bread, 1½ lb. or biscuit, 1 lb.; meat, fresh or frozen, 8 oz.; tea, ½ oz. or coffee, 1 oz.; condensed milk, $\frac{1}{20}$ tin; sugar, 2 oz.; fresh vegetables, 8 oz.; butter or margarine, 1 oz.; salt, ½ oz.; pepper, $\frac{1}{36}$ oz.; tobacco (weekly), 2 oz. Officers and men were to receive the same ration. In October 1914 the pepper was reduced to $\frac{1}{72}$ oz.

and 2 oz. of cheese was to be allowed as an alternative issue for 1 oz. of butter or margarine.

In November 1914 an addition of 2 oz. of peas, beans, lentils, or rice was made to this ration. In September 1915 an extra daily issue of 2 oz. of jam and 2 oz. of cheese was allowed for combatant prisoners employed on hard work outside their camps, when working pay was drawn; the ration was considered equivalent to about 4,600 calories a day, and instead of butter margarine only was issued to prisoners of war. Instructions were also issued that commandants were only to draw the actual amount of bread required; the prisoners were not necessarily entitled to 1½ lb. daily whether eaten or not, and in this way considerable saving was effected, as in several camps not more than 1 lb. per head was consumed.

In January 1916 the bread was reduced to 1 lb. and 6 oz. of flour issued in place of ½ lb. of bread.

In addition to the above ration, prisoners of war received a very large number of parcels full of black bread, sausages, etc. It was noted that in 1916, though the number of parcels had not greatly diminished, the quantity and quality of their contents showed a marked falling off.

On 1st May, 1916, owing to difficulty of making proper use of the flour in camps, the issue of 6 oz. of flour was withdrawn and the former ration of 1½ lb. of bread issued. In case of a flour ration being required, it might be drawn in the proportion of ¾ oz. of flour to 1 oz. of bread.

In December 1916 an extra issue of 2 oz. jam and 2 oz. cheese was allowed to non-combatant prisoners of war who were doing hard work outside their camps. It was also decided that lentils, swedes, and split peas might be drawn in place of potatoes, if desired.

In February 1917, after a full discussion in the Directorate of Prisoners of War, owing to the shortage of food in the United Kingdom, the prisoners of war diet was revised, and the following scale of rations was issued as a subsistence diet for prisoners doing no work of any kind: Bread, 9 oz.; meat, 6 oz. (five days a week); salt-cured herrings, 10 oz. or sprats or smelts, 12 oz. (two days a week); tea, ½ oz. or coffee, ¾ oz.; sugar, 1 oz.; salt, ½ oz.; potatoes, 4 oz.; swedes or turnips, 2 oz.; split peas or beans, 2 oz.; rice, 3 oz.; margarine, 1 oz.; oatmeal, 2 oz.; jam, 1 oz.; cheese, 1 oz.; pepper, $\frac{1}{72}$ oz. When engaged on manual labour, prisoners received an extra issue of bread, 4 oz.; cheese, 1 oz.; maize meal, ½ oz.

In May 1917 it was decided to issue the manual labour diet generally in camps, as commandants represented that practically all the prisoners were doing work of some kind, and an extra issue of 1 oz. of rice was also given. The ration thus provided was equivalent to about 3,000 calories. Commandants of camps were also informed that in the case of very heavy work extra issues of margarine, sugar, and rice might be made, which gave the total ration a value of at least 3,500 calories. Purchases in canteens or elsewhere of meat, sugar, or flour, were no longer permitted. Parcels containing any of these articles were not allowed to be purchased in the United Kingdom and sent to prisoners of war. No restriction was, however, placed on parcels sent from Germany. Officers and such other prisoners as drew no rations were permitted to purchase meat, sugar, and flour to the amounts advocated by the Food Controller for the civilian population in the United Kingdom.

In December 1917, potatoes being plentiful and the Food Committee of the Royal Society having drawn attention to their value and having recommended large issues for the use of the public, the diet scale of the prisoners of war was again revised, and 20 oz. of potatoes and 4 oz. of other fresh vegetables were issued. The daily issue was as follows: Bread, 9 oz.; broken biscuit, 4 oz; meat, 6 oz. (five days a week); salt-cured herrings, 10 oz. (two days a week); tea, ¼ oz. or coffee, ½ oz.; sugar, 1 oz.; salt, ½ oz.; potatoes, 20 oz.; other fresh vegetables, 4 oz.; split peas or beans, 2 oz.; rice, 1 oz.; margarine, 1 oz.; oatmeal, 1 oz.; jam, 1 oz.; cheese, 2 oz.; maize meal, ½ oz. Later the meat was reduced to 4 oz. and a weekly issue of either 8 oz. of salt-cured herrings and 2 oz. of oatmeal, or 4 oz. of salt-cured herrings, 2 oz. of oatmeal, and 2½ oz. of broken biscuit was made; the cheese issue was reduced to 1 oz.

In March 1918, owing to the shortage of meat supplies, the issue of 4 oz. of meat was temporarily replaced by 4 oz. of horse-flesh three days a week, and bacon 1⅜ oz., twice a week. When prisoners were employed on harvest work, 2 oz. of bacon were allowed.

In March 1919, supplies being more plentiful, the ration was increased, an issue of pork and beans once a week, and 3⅛ oz. bacon being made once a week; the margarine was also slightly increased. Employing the latest figures, based on recent analyses of food-stuffs, the protein, fat and

carbohydrate and calorie values of the various rations were as follows :—

TABLE II. 1919

Prisoners of War.	Protein.	Fat.	Carbohydrate.	Calories.
Light work	131	72	514	3,327
Hard work	131	100·6	514	3,591
No work—subsistence only	112	64	421	2,788

In France.—The scale authorized for prisoners of war in the United Kingdom was generally applicable to prisoners of war in France, but the following substitutions and additions were allowed :—

(i) When the full ration of potatoes (20 oz.) was not obtainable in France, extra rice or oatmeal was issued in lieu. For this purpose 1 oz. rice or oatmeal was considered as the equivalent of 4 oz. of potatoes.

(ii) 6⅔ oz. horse-flesh might be issued in lieu of herrings when the latter were not available.

(iii) 2 oz. edible fat per man per day was authorized as an additional issue, when considered desirable, to ensure increased labour output.

(iv) An extra 1⅔ oz. of bread was approved temporarily in March 1919.

When men were not employed on work in France the scale of deductions applied as regards summer only. No deductions were made in the rations of prisoners of war in France in winter months.

Extras were given to those employed on hard manual labour as authorized on the home scale ; and the purchase of foodstuffs and receipt of parcels were also subject to the same conditions as in the United Kingdom.

Equivalents, which could be issued only when components of the normal ration were not available, were as follows :—

Bread	1 oz.	= Biscuit	⅔ oz.
Meat (beef or horse-flesh)	4 ,,	= Preserved meat	3 ,,
		= Herrings	10 ,,
Rice	1 ,,	= Biscuit or oatmeal ..	1 ,,
Rice or oatmeal	1 ,,	= Potatoes	4 ,,
Margarine	1 ,,	= Edible fat	1 ,,
Split peas or beans ..	2 ,,	= Biscuit, rice, oatmeal, or maize meal ..	1 ,,
		= Bacon, margarine, or edible fat	½ ,,

If fresh or frozen meat was not available, preserved meat only could be issued in lieu, 1 lb. of the former being the equivalent of 9 oz. of the latter.

A ration of 12 oz. biscuit, 4½ oz. preserved meat, ½ oz. tea or ¾ oz. coffee, 1 oz. sugar, 1 oz. margarine, 1 oz. cheese, and 1 oz. jam was issued for journeys by train.

The daily train ration issued to prisoners of war when travelling from Italy to France consisted of 9 oz. bread or biscuit, 6 oz. preserved meat, 1 oz. cheese, ⅓ oz. tea, 1 oz. sugar, and ¼ oz. salt.

In Macedonia.—The ration for German and Austrian prisoners of war was similar to that allowed in France.

An issue of tobacco or cigarettes and matches was also made to prisoners employed on manual labour, who were deserving of the concession. Fuel and light issues were made on the same scale as to British troops.

Turkish and Bulgarian prisoners of war were given the following normal ration :—

	oz.
Bread	20
Potatoes and vegetables	12
Olives	1
Lentils and beans	2
Dried fruit	2
Sugar	2
Tea, or	½
Coffee	1
Salt	¼
Pepper	1/100
Cheese	2
Fresh meat, or	6
Horse-flesh	10½
Olive oil	1½
Rice	2
Lime juice*	1/10 gill
Charcoal	12

* Only issuable on days when fresh vegetables could not be supplied.

An issue of tobacco and matches was also made on the same conditions as for Germans and Austrians.

As equivalents, Turkish prisoners were given 8 oz. potatoes and vegetables for 3 oz. bread; 1 oz. cheese for 4 oz. bread, or 3 oz. dried fruit or 1½ oz. jam; 1¼ oz. rice for 1 oz. olives; 1½ oz. cotton-seed oil for 1½ oz. olive oil.

Where mule or horse-flesh was issued to labourers and prisoners of war in lieu of ordinary meat, the equivalent was 1¾ lb. mule or horse-flesh for 1 lb. meat.

An extra issue of ½ lb. bread was authorized for personnel

engaged in manual labour in mines and quarries, provided that the output of work warranted the increase.

In Egypt.—German, Austrian, and Bulgarian prisoners of war were given the following daily ration :—

Bread	9 oz.
Broken biscuits	4 „
Horse-flesh, or	4 „
Preserved meat (five days a week)	3 „
Bacon (one day a week)	1⅜ „
Salt, cured, smoked or pickled herrings (one day a week)	10 „
Tea	¼ „
Sugar	1 „
Salt	¼ „
Potatoes	20 „
Other fresh vegetables	4 „
Split peas or beans	2 „
Rice	1 3/7 „
Oatmeal	1 „
Cheese	4/7 „
Margarine	3/7 „
Pepper	1/100 „
Maize meal	½ „

To these rations a weekly additon was made of either 8 oz. of salt-cured herrings and 2 oz. oatmeal, or 4 oz. salt-cured herrings, 2 oz. oatmeal, and 2½ oz. broken biscuits.

On days on which fish was issued, ¼ oz. cotton-seed or cooking oil was authorized.

In the event of horse-flesh not being available, issues of bacon and herrings could be increased to two days a week in each case, and beef could be issued in lieu of horse-flesh on any of the remaining three days of the week, if necessary.

When potatoes were not available, 5 oz. onions, 4 oz. bread, 1 oz. rice, and 1 oz. beans or lentils could be issued in lieu of 20 oz. of potatoes.

Additions to scale for those doing light work were ½ oz horse-flesh (five days a week), 1 oz. margarine (daily), and 1 oz. bread (daily).

Additions to scale for those doing heavy work were 1 oz. horse-flesh (five days a week), 2 oz. bread (daily), 1 oz. sugar (daily), and 1 oz. rice (daily).

When prisoners were accommodated in camps, 2 lb. fuel wood or 1 lb. coal per man could be issued daily.

Three ounces of preserved meat were equivalent to 4 oz. of beef or horse-flesh.

The scale of rations for Bedouin prisoners of war was as follows :—

TABLE III.

	Sun., Tues., and Thurs.	Mon., Wed., and Sat.	Fri.
	Dirhems* unless otherwise stated.		
Bread	250	250	250
Oil	5	5	5
Meat, or	23⅓	—	—
Preserved meat..	18	—	—
Lentils	28	—	45
Beans	—	35	—
Rice	20	30	20
Onions	5	5	5
Cooked vegetables	21⅔	25	—
Uncooked vegetables	15	15	15
Cheese, native†	—	15	—
Olives or dates	15	—	15
Wood	2 lb.	2 lb.	2 lb.
Salt	5	5	5

* 9 dirhems = 1 oz. † When native cheese was not available a similar quantity of fresh meat was issued in lieu.

The scale of rations for Turkish prisoners of war was as follows :—

TABLE IV.

	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
	Dirhems, unless otherwise stated.						
Bread	209	209	209	209	209	209	209
Meat, or ..	—	23⅓*	—	23⅓*	—	—	23⅓*
Preserved meat	—	18	—	18	—	—	18
Vegetables ..	45	45	45	45	45	45	45
Rice	26⅓	26⅓	26⅓	26⅓	26⅓	26⅓	26⅓
Oil or margarine	9⅓	9⅓	9⅓	9⅓	9⅓	9⅓	9⅓
Pepper	—	⅛	—	⅛	—	—	⅛
Salt	5	5	5	5	5	5	5
Onions	5	5	5	5	5	5	5
Tea	⅙ oz.	⅙ oz.	⅙ oz.	⅙ oz.	⅙ oz.	⅙ oz.	⅙ oz.
Sugar	⅔ ,,	⅔ ,,	⅔ ,,	⅔ ,,	⅔ ,,	⅔ ,,	⅔ ,,
Cheese	20	20	20	20	20	20	20
Olives or dates..	15	—	15	—	15	—	15
Lentils, beans or dried peas ..	35	35	35	35	35	35	35
Wood	2 lb.	2 lb.	2 lb.	2 lb.	2 lb.	2 lb.	2 lb.
Cigarettes (weekly) ..	1 oz.	—	—	—	—	—	—
Matches (weekly)	1 box	—	—	—	—	—	—
Wheat	36¼	36¼	36¼	36¼	36¼	36¼	36¼

* Or preserved meat, 18 dirhems.

Equivalents were arranged for by substituting 1 part by weight of dates, raisins, or currants, or 1 part by weight of lentils, beans, or dried peas, for 1½ parts by weight of bread, 1 part of wheat, 0·9 of rice or 0·8 of oatmeal.

There was a special scale of rations for Turkish prisoners of war in working camps at Kantara and east of the Canal. It was composed of the following articles :—

TABLE V.

	Mon., Wed., Fri. and Sat.	Tues., Thurs., and Sun.
Bread	32 oz.	32 oz.
Meat (including bone) or	4 ,,	4 ,,
Preserved meat	3 ,,	3 ,,
Vegetables	4 ,,	4 ,,
Rice	3 ,,	3 ,,
Oil or margarine	¾ ,,	¾ ,,
Pepper	—	1/100 ,,
Salt	½ ,,	½ ,,
Onions	½ ,,	½ ,,
Tea	¼ ,,	¼ ,,
Sugar	1 ,,	1 ,,
Dates or olives	2 ,,	2 ,,
Lentils, beans, or dried peas	4 ,,	4 ,,
Wood	1¼ lb.	1¼ lb.
Cigarettes	1 oz. weekly	—
Matches	1 box ,,	—

In Mesopotamia.—There were two scales of rations for prisoners of war in Mesopotamia, one for officers and the other for rank and file. Officer prisoners of war received the following rations :—

Bread	16 oz.	daily
Fresh meat	8 ,,	
Potatoes or fresh vegetables	12 ,,	
or dried vegetables if fresh vegetables not available	3 ,,	
Sugar	3 ,,	
Coffee, if available, or	1½ ,,	
Tea	¾ ,,	
Salt	½ ,,	
Fresh fruit, or	2 ,,	
Dried fruit if fresh fruit not available	1 ,,	
Rice	2 ,,	
Ghi	2 ,,	
Fuel (coal, 1 lb.; wood, 1 lb.)	2 lb.	
Tobacco, or	2 oz.	weekly
Cigarettes	40	
Matches	3 boxes (fortnightly)	
Marmite (not in summer)	¼ oz. (Mon. and Thurs).	
Lime juice (not in winter)	½ fl. oz. (Tues., Thurs., and Sat.)	

The rank and file prisoners of war received the following :—

Atta	16 oz.	daily
Rice	6 ,,	daily
Fresh meat, or	6 ,,	daily
Preserved meat when fresh meat not available	4½ ,,	daily
Ghi	2 ,,	daily
Fresh vegetables	6 ,,	daily
Tea	⅓ ,,	daily
Sugar	⅓ ,,	daily
Salt	½ ,,	daily
Fuel wood	2 lb.	daily
Cigarettes	40 (weekly)	
Matches	3 boxes (fortnightly).	
Dhall	4 oz.	twice weekly.
Tamarind	1 ,,	twice weekly.
Lime-juice	⅓ oz.	Tues., Thurs., and Sat.
Sugar	½ ,,	Tues., Thurs., and Sat.
Lime juice	1 oz.	Sun., Mon., Wed., and Fri.
Sugar	⅓ ,,	Sun., Mon., Wed., and Fri.
Dates	2 oz. (five times weekly).	

Food Parcels.

The following extract from the Official Report on the Directorate of Prisoners of War, gives interesting information concerning the transmission of food parcels to prisoners of war in the United Kingdom as well as to British prisoners of war.

" *Despatch of Food to British Prisoners of War.*—Even in the earliest stages of the war, when supplies were ample, no enemy country fed its prisoners of war properly. In Germany, where prisoners, and especially the British, were regarded and treated as criminals, no attempt was made to do this. The question of keeping British prisoners supplied with the mere necessaries of existence, therefore, came early to the fore, and was at first attempted by a number of independent bodies—regimental societies, town committees, and such like, who despatched food and goods without any supervisory control.

" In March 1915 the Prisoners of War Help Committee was formed to exercise general supervision over the despatch of supplies to prisoners, but it lacked authority and was unable to curb the philanthropic but unorganized zeal of the various independent societies. While many were willing to act under the instructions of the Committee, others held aloof, and the result was that the distribution among prisoners of war was most unequal. Some were receiving an excessive amount of supplies, others got little or nothing. A check on one delivery of letters from Bulgaria brought to notice the case of a prisoner from whom five letters were received, some of thanks to different donors for parcels of food, and others begging for assistance as he was 'starving.' This form of fraud had been suspected for some time. It was evident that closer supervision, backed by stringent regulations, was necessary. This was undertaken by the Central Prisoners of War Committee of the British Red Cross Society and Order of St. John, in December, 1916; but it was not at first made applicable to officers.

" The restrictions imposed by the War Office were directed towards efficient censorship, the equalization of distribution, and the prevention of entry into hostile countries of any goods not really necessary for the prisoners, and thereby, the maintenance of the blockade. These restrictions, the novelty of the scheme, and especially the prohibition against the despatch of private

parcels of food and clothing from relatives caused much discontent throughout the country, and indeed the Empire. A joint Committee of the two Houses of Parliament investigated the whole matter in the summer of 1917. Certain shortcomings were brought to light, but the scheme as a whole was left intact; and thanks to the capable and whole-hearted manner in which it was carried out by the Central Prisoners of War Committee and the affiliated societies, proved a great success.

"All parcels despatched by or under the authority of the Central Prisoners of War Committee were covered by Red Cross guarantee, and stringent steps had to be taken to ensure that none but authorized articles were included in them. In addition to food, this Committee sent drugs and medical appliances to our men.

"The Central Prisoners of War Committee have issued a comprehensive report on their work. Their considered opinions are valuable.

"*Despatch of Clothing to British Prisoners of War.*—Owing to the failure of enemy Governments to supply proper or an adequate amount of clothing to prisoners, which in the later stages of the war was largely due to the increasing stringency of the blockade and consequent scarcity, it was necessary to despatch parcels of clothing as well as food to British prisoners.

"*Prohibition of Parcels, an easy means for Enemy to exert Pressure.*—The great and frequently expressed anxiety as to British prisoners in hostile countries suggested a ready means to our enemies to exert pressure. Germany, especially, took advantage of this from time to time by imposing needless delays in delivery, and by the meticulous censorship of correspondence and parcels. Regardless of agreements reached between the two Governments, a commandant would not infrequently hold up all parcels which had reached his camp, on some totally inadequate pretext. Retaliatory action by us was hardly practicable, as, owing to the scarcity in Germany and the sufficiency of the food supplied to German prisoners, the number of parcels they received was not comparable to those sent from this country. In fact, enemy Governments had in the prohibition or detention of parcels one of their strongest weapons, and we never dared to risk serious action being taken by them, which would have caused a vast amount of misery to British prisoners and an outcry in the Empire.

"*Agreements with Enemy Governments.*—Much correspondence, lasting in each case for months, took place with the German Government on the subject of penal restrictions on letters and parcels, the delivery of parcels to prisoners undergoing punishment, and the procedure for dealing with parcels which could not be delivered. The agreements which were eventually reached on these subjects are given in Army Council Instructions 337 of 1916, and 1254 and 1277 of 1917. Special instructions, supplementary to those given in Army Council Instruction 1277 of 1917 regarding undeliverable parcels, were issued for use in the United Kingdom, where the requirements of labour necessitated frequent changes of camp.

"The German authorities having failed, especially in the case of those held by them in occupied territory, to fulfil their undertaking that a prisoner under sentence should be permitted the same privileges as regards correspondence as were granted to other prisoners of war, a regulation was issued in August 1918 whereby a German prisoner under sentence of twenty-one days or less, outside a theatre of operations, was permitted to write and receive only one letter while under punishment. If the sentence were of longer duration, the ordinary rules as to correspondence were applied. Those undergoing sentences in any theatre of operations were allowed, irrespective of the length of sentence, to write and receive only one letter a month unless the local military authorities permitted the receipt of more. This measure brought British practice into line with that adopted in Germany.

"*Limitations on Food sent to Prisoners of War in the United Kingdom.*—As with the course of the war food-stuffs in the United Kingdom became scarcer, regulations were issued of increasing stringency as to the contents

of inland parcels despatched to prisoners of war interned in the United Kingdom, culminating in June 1918 in the absolute prohibition of any article of food being included in any parcel despatched to a prisoner of war from any person in the United Kingdom or any Dominion or Colony. These restrictions affected few except civilians who had been resident in the country before the war, and whose families or friends had not been interned."

The equitable adjustment of the contents of food parcels at different stages of the war was a matter of concern to the hygiene authorities. There was ample evidence that the ration allowance of British prisoners of war in Germany was dangerously low, even if all the articles of diet were completely edible. From the evidence of prisoners, particularly of those arriving in Switzerland and examined there by neutral authorities, it had to be accepted that a great part even of the meagre ration was of unwholesome quality and uneatable. These prisoners presented a picture of malnutrition.

The figures in Table VI are examples of the daily scale of rations given to British prisoners of war, as ascertained for several camps, at a time when the German soldier was having a dietary representing 4,000 calories. The quantities are in grammes.

TABLE VI.

Camp.	Date.	Protein.	Carbo-hydrate.	Fat.	Total Calories.	Estimated "Edible" Calories.
I	April 1917 ..	21·24	108·09	3·58	759·64	527·30
II	August 1917 ..	29·92	159·72	3·65	990·08	807·50
III	September 1917..	61·08	326·99	8·16	—	1,643·99
IV*a*	October 1917 ..	30·97	163·42	3·78	—	827·50
IV*b*	" " .. (Hard workers)	40·10	199·42	4·55	—	1,018·00
V	November 1917..	45·45	215·22	5·73	1,349·00	1,119·00
VI	December 1917..	35·34	172·81	4·24	1,105·00	893·60

From these ascertained scales of rations the estimate of the "edible" calories gives a diet worth on the average only about 846 calories per man per day. The attempt was made to ensure the supplementing of this dietary by some 2,600 calories, by appropriate selection and constitution of the food parcels sent from this country by the Central Prisoners of War Committee. Thus a ration of 3,500 calories should have been attainable, which is the value considered necessary for men doing moderate work.

By the end of 1917 the packing of parcels for prisoners of war became a work of considerable complexity and volume. The authorities were concerned at the increase in bulk of the

supplies being sent into Germany for newly captured prisoners, prisoners on transfer, and others. Reconsideration of the contents of parcels and of their calorie value was thrown on the Prisoners of War Committee and on the hygiene advisers of the War Office. The question of the reduction of bread-stuffs arose at the same time, as much anxiety and enormous expenditure were involved in the matter of obtaining from America the large quantity of flour required by the Committee and imported to Berne and Copenhagen for bread-making and distribution. Diplomatic and maritime difficulties also were causing embarrassment.

Some indication of the constitution of the food parcels, of which the number suggested for each prisoner was four monthly, and of their calorie value is given in the following tables.

TABLE VII.

Parcel A.

		Calorie Value.	
Beef	1 lb.	Proteins	368·7 grm.
Vegetables	½ „	Carbohydrates ..	643·3 „
Sausages	1 „	Fats	605·1 „
Cheese	1 „	Calories ..	9,669
Tea	¼ „	Add bread, 8 lb.	
Milk	1 „	Calories ..	9,976
Sugar	½ „		
Dripping	½ „		
Rations	1 „		
Cigarettes, or	50		
Tobacco and cigarette papers	2 oz.		
Soap	¼ lb.		
Veal loaf	½ „		
Marmite	1 jar.		
Quaker Oats	¼ lb.		
Soup	1 jar.		

Weight when packed, 10 lb. 15 oz.

Parcel B.

		Calorie Value.	
Rations	1 lb.	Proteins	284·5 grm.
Marmite	1 jar.	Carbohydrates ..	914·4 „
Bacon	½ lb.	Fats	1,125·2 „
Cocoa	¼ „	Calories	12,170
Sausages	1 „	Add bread, 8 lb.	
Dripping	½ „	Calories ..	9,976
Baked beans	1 „		
Cigarettes	50		
Milk	½ „		
Syrup	1 „		
Sardines	½ „		
Soap..	¼ „		
Sugar	½ „		
Ham loaf	½ „		
Quaker Oats	½ „		

Weight when packed, 10 lb. 12 oz.

TABLE VII—*cont.*

Parcel C.

		Calorie Value.	
Beef	1 lb.	Proteins	335·5 grm.
Salmon	1 „	Carbohydrates	1,056·9 „
Milk	1 „	Fats	603·2 „
Tea	¼ „	Calories	11,092
Sugar	½ „	Add bread, 8 lb.	
Marmite	1 jar.	Calories	9,976
Chocolate	¼ lb.		
Beef loaf	½ „		
Suet pudding	1 „		
Dripping	½ „		
Quaker Oats	¼ „		
Soap	2 oz.		
Baked beans	1 lb.		
Jam	1 „		

Weight when packed, 11 lb.

Parcel D.

		Calorie Value.	
Beef	1 lb.	Proteins	347·3 grm.
Bacon	½ „	Carbohydrates	836·1 „
Cocoa	¼ „	Fats	856·8 „
Milk	½ „	Calories	13,323·7
Sausages	1 „	Add bread, 8 lb.	
Dripping	1 „	Calories	9,976
Cigarettes	50		
Jam	1 „		
Quaker Oats	¾ „		
Soap	2 oz.		
Sugar	½ lb.		
Herrings	1 „		
Chocolate	¼ „		
Sardines	½ „		

Combining parcels A and D and parcels B and C and adding 8 lb. of bread to each parcel, a daily calorie supply of 2,354·8 and 2,374 respectively is obtained. The continued supply of 13 lb. instead of 8 lb. of bread would make a more favourable diet; but as the protein supply of the German ration was the most objectionable item the certain supplement of the proteins took first place.

It was, however, attempted to maintain the earlier combination of three parcels every fourteen days and 13 lb. of bread. The commodities were practically the same and the calorie value of the combinations of the parcels ranged from 31,127 to 33,182, the parcels separately having equivalents of A 10,416, B 12,194, C 10,572, and D 10,139 calories.

Diseases.

In the United Kingdom, with the exception of influenza in 1918, infectious disease was rare amongst prisoners of war. In general also the health of prisoners was satisfactorily maintained. In 1918, when influenza in epidemic form was widespread

in the country, many camps remained entirely exempt, and only at two, Kegworth and Handforth, did the disease assume serious form. In the former, out of a total of 35 deaths occurring from the inception of the camp in 1916 till its close, 34 resulted in 1918 from virulent influenza. At Handforth, 11 deaths were due to influenza in 1918, out of a total death-roll of 19 in the years from the opening of the camp in 1914.

At the prisoners of war camp on the Isle of Raasay, amongst prisoners employed in ironstone quarrying, an outbreak of scurvy occurred, of which the following report is a brief summary :—

"The number of prisoners in this camp was 253, of whom 94 were employed as miners in the ironstone mines of Raasay. The remaining prisoners were employed at the pit-mouth, pier-head, or on camp fatigues. The men were accommodated in good cottages, there were a good water supply, water carriage system of sewage, ample bathing and cooking facilities. The outbreak commenced about the beginning of June 1917, and previous to it there had been a certain amount of influenza during May. The first symptom noticed was the development of large bruises after the most trivial injuries. The cases gradually increased in number and complaints of weakness and inability to perform a full day's work became common. But it was not until the first week of July, when a case developed spongy and bleeding gums, that scurvy was diagnosed. On 12th July there were 82 cases of scurvy, the men being anæmic and having spongy gums. Hæmorrhagic effusions were common in the calves and inner side of the thighs and also over the front of the legs. Where there were no hæmorrhagic effusions, purpuric spots were present over the calves.

"Of the 94 prisoners employed in the mines, 30 were doing the light work of boring and 64 filled the hutches with iron stone. Of the 82 cases of scurvy, 63 occurred in the men working in the mine and 19 in men following other occupations.

"The daily rations received by all the prisoners at that time were : Bread, 13 oz. ; meat, 6 oz. (five days a week) ; salt-cured herrings, 10 oz. (two days a week) ; sugar, 1 oz. ; swedes or turnips, 2 oz. ; rice, 4 oz. ; margarine, 1 oz. ; oatmeal, 2 oz. ; jam, 1 oz. ; cheese, 2 oz. ; maize meal, 1½ oz. ; tea, ⅜ oz. The issues had a calorie value of about 3,040.

"Professor Leonard Hill visited Raasay and enquired into the probable cause of the outbreak of scurvy. He reported that before the restriction in prisoners' diets came into force 'they had received a ration of potatoes, they also bought bacon with the money they earned by their work, and, they ate this bacon raw.' Enquiring into the methods of cooking, Professor Hill found that the Commandant issued the rations to the prisoners and allowed them to cook the food as they pleased. The meat was first roasted and then stewed in water thickened with flour or meal supplied, to which the swede or turnip ration was added, the whole forming a very nourishing and appetizing thick soup, or 'goulash,' much favoured by the prisoners. The stew was boiled for two hours and then kept simmering, with enough fire under the boiler to keep it hot for another three hours, when the prisoners had their meal. Thus the fresh meat, together with the swede or turnip ration, was submitted to five hours' cooking at a temperature of or approaching 100° C., which must destroy the anti-scorbutic principles. To this method of cooking, Professor Hill primarily attributed the outbreak of scurvy. He considered that the 2 oz. of swedes or turnips and the 6 oz. of boneless fresh meats, issued five days a week, if properly cooked, would have sufficed to keep away scurvy. He estimated that the prisoners' diet was equal in energy

value to that of the German soldier in 1916–17, and superior to that of the German munition worker, and that it was not inferior but even superior to the diet supplied in some of the hostels and canteens to British munition workers.

"Professor Hill did not agree with the view that the outbreak of scurvy, which most particularly affected the miners, was attributable to the restricted ration being altogether insufficient in energy value for the work done. He made a careful estimate of the calorie value of the work done and came to the conclusion that the restricted diet of 3,000 calories provided ought to be ample. He noted that the work done in climbing and walking to and from the mine was very much greater than that done in the mine by those prisoners who filled the hutches; there was not, therefore, so great a disparity as had been supposed between the work done by these prisoners and by those who did rock-drilling and other lighter jobs. The prisoners who filled the hutches were, however, stimulated to do the work rapidly, which caused excessive production of fatigue products. The extra work thus done and the extra nerve energy expended by the hutch workers would well explain why these men particularly suffered in the outbreak.

"The method of cooking was changed, and prolonged stewing of the rations no longer permitted. Extra issues of margarine, sugar, and rice were allowed on the recommendation of the medical officer in charge of the camp, for men who were not in good condition or losing weight. The calorie value of the ration with extras was 3,500. No further cases of scurvy occurred in the camp."

Pellagra occurred amongst Turkish prisoners of war in Egypt. Of the origin of the disease, the conclusion of the Committee of Investigation is that "the cases were generally pellagrous prior to capture. The great majority of cases, systematically questioned, stated that they had similar symptoms before capture; while among the Turkish prisoners examined shortly after capture many were found suffering from the developed disease, *e.g.*, 18 per cent. of one group of 1,300 seen on arrival direct from the front."

Except towards the autumn of 1918, minor diseases were also not much in evidence amongst prisoners of war in the United Kingdom, the supervision, overseas and in transit, having been during the early part of the war sufficient to combat these. But when large numbers of prisoners were being sent over in the last year of war, emaciation, malnutrition, and pediculosis, with resulting skin lesions in variety, were frequent. It is reported also that there was evidence at this time of much tuberculosis. Many of the prisoners of these days were young or low category men whose physique had never been good. They evidently suffered from malnutrition and exposure, and were badly clothed and shod. Pediculosis was frequent and severe, while the sufferers from ulcerating chilblain and trench foot were numerous. Prompt and radical measures of depilation and cleansing, disinfestation of clothing, and provision of clothes and boots, were taken in regard to these prisoners on an extensive scale on their arrival in England.

Diseases amongst prisoners on the different army fronts naturally were similar to those of the armies in the same situations and subject to the same climatic and topographical influences. Of these perhaps the most widely prevalent, at least on certain fronts, was malaria, which received the same control amongst prisoners as amongst the British troops.

Defence against the introduction of such potentially epidemic diseases as typhus, smallpox, cholera, and plague was a constant measure of prevention by medical officers. Examples of the measures adopted against the importation of cholera, typhus and other epidemic diseases by prisoners of war are shown in the routine orders in Appendix A.

During the period of repatriation, following the date of the armistice and the conclusion of peace, much involved work fell on the medical personnel in supervising prisoners of war, both well and sick, in their movements, rationing, accommodation *en route* by ship, rail, and on the march, and in averting danger of transmission of infection. This applied especially to returning British prisoners of war. The disorganized condition of Germany at the time brought about relaxation of the normal supervision there of the British prisoners of war. Many prisoners left their camps and made for the nearest allied or neutral country. In some camps the men organized themselves. Considering the large numbers of prisoners transferred within a comparatively short time in both directions, it might be safely assumed that the period of repatriation was fraught with even greater danger of spreading epidemic disease than was the period of war and movement of troops. Special machinery was set in motion with the help of the authorities in Holland, Denmark, and elsewhere where prisoners of war first arrived, to control their clothing, rationing, disinfection and disinfestation, and supervise their transport. Much valuable work of a preventive nature was thus performed, the fruits of which are apparent in the absence of epidemic of any kind attributable to repatriation.

CHAPTER VI.

THE MILITARY PHYSICAL TEST STATION IN EDINBURGH.

IT became evident during the war that some men who were organically sound were nevertheless incapable of sustained exertion, and among the older group who were called to the colours in 1918 the proportion of such individuals was considerably increased. The effect of forcing these men to carry out the duties falling to the lot of a recruit of the highest physical category was in many cases harmful to them and in extreme instances caused permanent disability or even graver results. The Army Medical Department therefore sought to obtain a method of physical examination which would supplement the ordinary medical examination of a recruit and enable the malingerers to be distinguished from those who were incapable of sustained labour.

At that time, Professor Henry Briggs was working on the same problem in its application to the members of mine rescue brigades,* who, like the soldier, ought to be both medically sound and physically efficient, and he succeeded in developing a method of testing which quantitatively assesses fitness and stamina. Acting on the advice of Colonel Sir William Horrocks, the Army Council put the method into service for army purposes by setting up in Edinburgh University the Military Physical Test Station. Arrangements were being made in the autumn of 1918 to establish a second station under the Southern Command, but the signing of the armistice in November brought the project to an end, and shortly after the Edinburgh station also ceased to function.

The principle upon which the method is based and the experimental data bearing upon it have been fully described in the *Journal of Physiology* and in the *Journal of the Royal Army Medical Corps*.

It was found that when a man breathing normal air is set to do physical work of gradually increasing amount, as, for example, upon a Martin's ergometer, the percentage of CO_2 in the exhaled air rises from the resting value (average, 3·61) to a maximum and then falls again. That is to say, if that

* This work was carried out under the auspices of the Scientific and Industrial Research Department, which also provided the material for the Test Station.

percentage be plotted as ordinate against load in foot-pounds per minute as abscissa, a dome-shaped curve (*e.g.*, A, Fig. 1) always results. The evidence supports the view that oxygenation of the muscles doing the work is sufficient up to a load corresponding with the apex of the dome (the " crest-load,"

FIG. 1

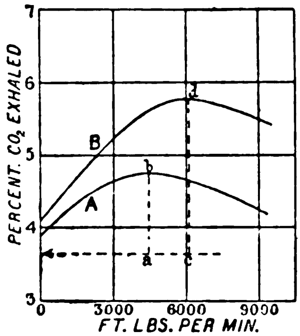


FIG. 2

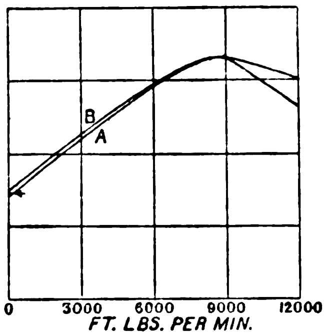


FIG. 3

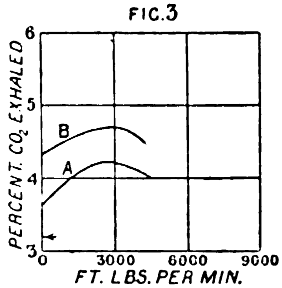
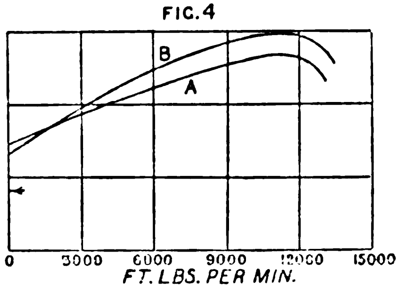


FIG. 4



as it is conveniently called), but is inadequate for greater loads. Degrees of exertion which are less than the crest-load are termed " normal-loads " and can be supported for a considerable time, while those exceeding the crest-loads are " over-loads " and cannot be kept up for more than a brief period. Fatigue or illness reduced the " crest-load."

When the subject is made to breathe air containing from 60 to 100 per cent. of oxygen the effect with most people is to enable them to undertake hard physical work with greater ease and to carry it on longer without fatigue. In other words, oxygenation is improved. The result of breathing enriched air becomes evident when the graph connecting the degree of

exertion and the expired CO_2 percentage is drawn (as at B, Fig. 1). It is then seen, with the average subject, that the CO_2 proportions are higher, especially at and beyond the crest-load, and that the crest-load itself is greater than when normal air was breathed. Oxygen want, which is the main factor limiting the duration and intensity of physical exertion, is staved off by breathing enriched air.

By experimenting on a large number of healthy men ranging in type from the athlete in perfect training to the ultra-sedentary person it was found that the higher the degree of fitness the less the A and B curves diverged, and, indeed, that when exceptionally fit men were tested the resulting graphs were similar to those of Fig. 2, where the curves for all practical purposes are coincident to the crest and only show divergence at the over-loads. It was also discovered that if the same men were kept under observation for several months and were tested during different states of health, or at intervals during a course of physical training, the B curve would remain constant (within the limits of experimental error), but the A curve would vary in form and position according to the state of health or of training. Fitness, which may be defined as the efficiency of oxygenation of brain, heart, and muscles during exercise, is therefore inversely as the extent of divergence of the two curves, and can be evaluated.

By drawing upon the graph the horizontal line *ac* (Fig. 1) at the level of the expired CO_2 percentage at rest and then measuring the crest ordinates *ab* and *cd*, the fitness factor can be expressed as $ab \div cd$. Thus, Fig. 1, which records the data for a sedentary man, gives his fitness as 46 per cent., while the curves of Fig. 2, which are those of an athletic sergeant-instructor in physical drill, show his fitness to have been 100 per cent.

If stamina be defined as the power of dealing with sustained exertion, it is clear that the wider the range of normal-load, *i.e.*, the higher the crest-load, the higher must be the stamina of the subject. Hence the abscissal position of the crest-load becomes a measure of stamina.

Inasmuch as the A curve of a young man in good health rises during physical training until it eventually coincides with the B curve up to the crest, the latter curve may be regarded as expressing the subject's performance on air after he has been made quite fit; thus it was preferable to state the stamina as a function of the position of the crest of the B curve. The measure of stamina adopted at the test station was to

take a B crest-load of 10,000 ft. lb. per minute as indicating 100 per cent. stamina, a B crest-load of 5,000 ft. lb. as 50 per cent. stamina, and so on. This method, though not free from objection, is simple and proved reliable.

FIG. 5

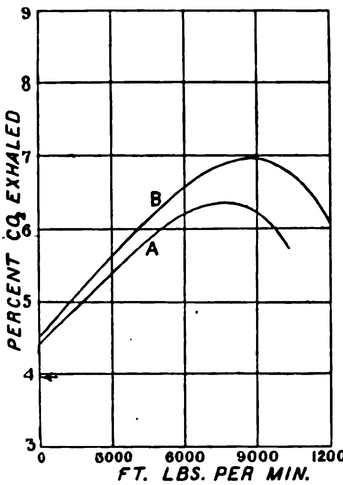


FIG. 6

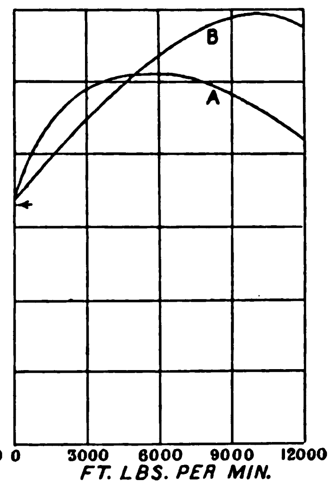


FIG. 7

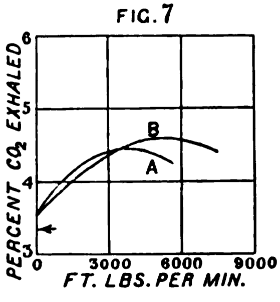
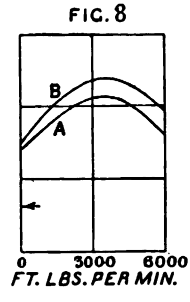


FIG. 8



The station was run by an officer and two N.C.Os., under the superintendence of Professor Briggs. In the research which preceded the establishment of the station, apparatus of rather greater complexity had to be employed, since the aim then was to evaluate oxygen consumption during work as well as CO_2 output, and to study other questions, such as the composition of alveolar air and the mechanical efficiency of the subject ; but at the station the apparatus was cut down to the minimum and the routine was simplified and standardized for the sake

of speed. The whole equipment, with the exception of thirty 100-ft. oxygen cylinders, is shown in Fig. 9. The subject, it will be observed, was provided with mouth-piece and nose-clip ;

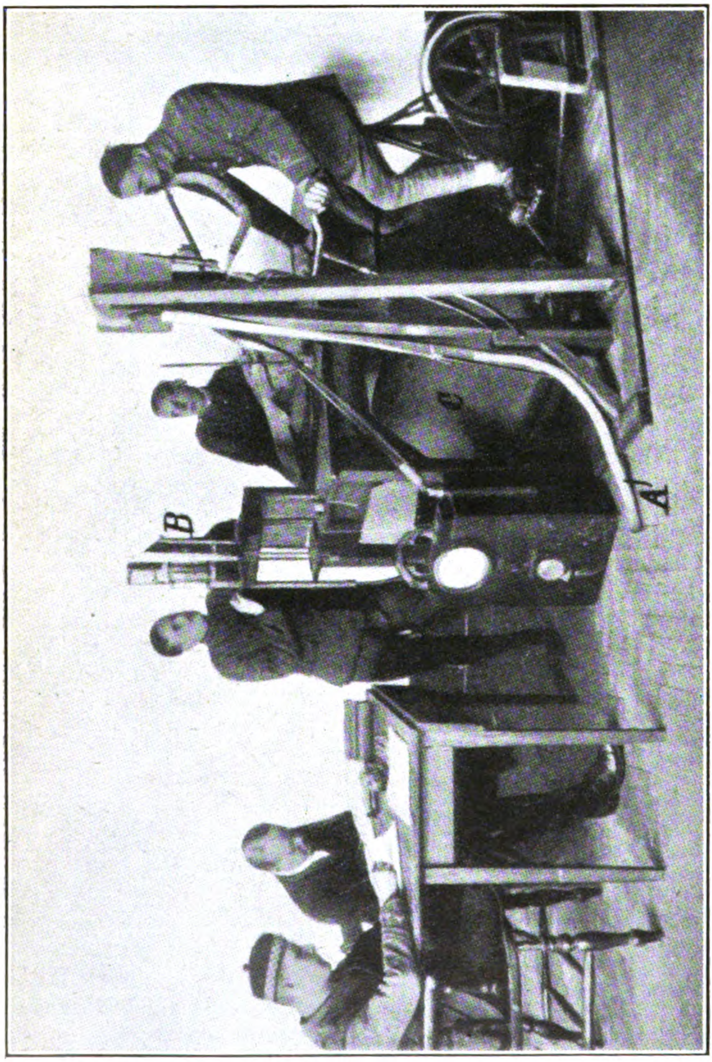


Fig. 9.—Testing with the ergometer, Physical Test Station, Edinburgh.

he drew air or oxygen (as the case might be) through a dry meter and expired into a Douglas' bag. The valves and connecting tubes were large, and their resistance was negligible

even when the lung ventilation was as high as 80 litres per minute. The meter, besides measuring the volume drawn in, served to indicate the rate of breathing; the officer in charge counted the movements of the pointer against a stop-watch. As the dial of the meter was not seen by the man he was unaware that any notice was being taken of his breathing—a matter of importance with raw subjects.

At the start, the empty Douglas' bag was connected to the expiratory tube, A, the three-way tap being in the "off" position, so that the products of expiration passed directly out into the air of the room. The subject, seated at rest on the saddle, breathed normal air. After he had become accustomed to his position the three-way tap was turned "on" at the end of an expiration and the breath passed into the bag. After an interval of about two minutes the tap was again turned at the end of an expiration. The bag was then placed on the table; kneaded to mix its contents; connected to the supply pipe of the Briggs analysis apparatus, B, and with the tap in the "on" position, squeezed to force a few litres through the burette. The sample so obtained in the burette was then analysed for CO_2. This procedure avoided the need for sample tubes or bottles. One of the N.C.Os. made the analysis during the time that the next sample was being obtained in the bag.

After filling the burette the bag was emptied by pressing it flat and was again connected to A. The subject was required to pedal at no load, *i.e.*, with the belt off, for two minutes; the tap was turned on at the end of an expiration, and expired air allowed to accumulate in the bag for another two minutes of pedalling, when the sample was removed to the analysis apparatus. The belt was put in place; its cords were adjusted to give a difference of 3 lb. between the balance readings, and the same sequence followed. Similar observations were made at balance differences of 6, 9, 12 lb., or even more, if the man could support such heavy exertion.

Pedalling was timed to a pendulum which swung 56 to the minute; at this rate, and with the gear of the cycle used, the work done was evaluated by multiplying the balance difference by one thousand.

Longer pauses were permitted between the heavier spells of work to allow the man to recover from the effect of one spell before attempting another. Care was taken that pedalling was kept up two minutes before opening the bag to the exhaled air; at the highest loads, however, *e.g.*, 12,000 or 14,000 ft. lb.

this rule had to be relaxed as no one was able to bear them so long. The graphs at these extreme loads are therefore not so reliable as at lower ones.

After the above results had been obtained with the subject breathing normal air, an exactly similar series, with the resting experiment omitted, was taken with the man breathing oxygenated air from a reservoir bag which was kept, in a partially distended state, under the table at C, Fig. 9. Before the latter series was started he was required to sit still and breathe the enriched air for ten minutes.

The subject did not know that he was breathing oxygenated air. No loophole was allowed for any prejudice against so doing.

The oxygen was supplied to the reservoir bag, C, from a 100-ft. cylinder fitted with a reducing valve. On passing the reducing valve the gas flowed through an injector nozzle arranged so that the oxygen drew in, and diluted itself with a certain proportion of normal air. The air entered through a pipe controlled by a tap which was set by trial and then soldered in position, so that the mixture passing forward to the reservoir bag was 40 per cent. air. Allowing for the impurity in cylinder oxygen, such a mixture contains about two-thirds oxygen. Besides the mixture being as good from the physiological point of view as pure oxygen, even with the least fit subject, its use brought about a considerable saving in expense, as oxygen was the chief item in the cost of the station.

The officer in charge entered all results as they were obtained and immediately plotted the graphs. A report, based upon his medical history and test station performance, was made out for each subject and forwarded to the commanding officer concerned. The report stated the physical capability of the man and his probable utility when trained. In the numerous instances where the tests showed him to be useless for fighting purposes a recommendation was added in regard to the work, if any, to which he could be put.

A complete test, as described, took about thirty-five minutes. The time taken obviously precluded the use of the method for every recruit, and that was never the intention; the station was set up to deal with special cases.

Specimen curves are reproduced in Figs. 1 to 8. The arrow-heads indicate the resting value of the CO_2 proportions. The A curves show the relation between load and expired CO_2 percentage when breathing normal air and the B curves that when breathing oxygenated air.

When the station was in operation men over 40 years of age were being called up for service, and many of these were examined. Only about 20 per cent. of them gave evidence of being suitable for training. The graphs indicated very clearly the influence of age, which reduces the " crest-loads " both on normal and on enriched air. In other words, anoxæmia, as might be expected, makes itself felt lower down the scale of exertion as age increases; stamina is reduced and a degree of exercise which would be a normal-load to a younger man is an over-load to an older one. The effect in question is shown by Figs. 3 and 4, of which the former is the record of a man of 44—a painter in civilian life—who was classed " B2 " owing to kidney trouble, and the latter that of a well-developed and athletic cadet of 18. The report sent out in regard to the older man was: " *Stamina:* Very poor. *Condition:* Poor. *Observations:* Not worth training; no use as an infantryman. *Recommendation:* Suggest that he be set to his own trade." And that in regard to the cadet was: " *Stamina:* Excellent. *Condition:* Excellent. *Observations:* First-rate material; fit for anything. Probable increase of fitness from physical drill 10 per cent."

That a man of middle age, who is habituated in civilian life to physical labour, may sometimes preserve the physiological characteristics of youth is illustrated by Fig. 5, which gives the curves of a working miner, aged 42. Expressed on the system above described, his fitness was 79 per cent. and his stamina 90 per cent.

The physical deterioration brought about by wounds and hard active service is indicated by Fig. 7. In this instance the subject was a corporal, aged 32, who had joined the army in 1914; he had suffered from trench fever and had been wounded three times. His medical category was " A1," but the tests showed that, though probably as fit as he was ever likely to be, his stamina had become so impaired that he was of no further use as an infantryman, and it was recommended that he should be re-examined so that his category might be lowered.

The curves, Figs. 6 and 8, are of special interest as representing the extremes of physical capacity. Both subjects were young men of " A " category; but, while the former (Fig. 6) was a highly intelligent instructor in physical drill, and a first-class all-round athlete at football, running, and jumping, the latter (Fig. 8) was deficient both physically and mentally.

When the curves of Fig. 6 were obtained the subject had a fitness of 70 per cent.; on the lightest loads he

respired at the very low rate of 2·5 to 3 breaths per minute, and when dealing with a heavy load, like 12,000 ft. lb., he only breathed 9 times per minute. As the chart shows, his CO_2 level was very high and in consequence he used a small volume of air. For example, on a load of 6,000 ft. lb., though the heavier man, his lung ventilation was less than half that of the sedentary subject of Fig. 1.

A good deal of trouble was taken with the subject of Fig. 8. He did not know how to pedal, and even after practice could not be induced to pedal in time with a pendulum. The record shows him to be useless in the ranks and not worth training; his stamina was far too low. His response to any form of mental stimulus was unusually tardy. An order, such as "stop pedalling," would only be obeyed after the lapse of several seconds. Curiously enough, his respiratory centre appeared to operate after a similar lag, with the result that the volume of breathing did not increase at the normal rate upon starting a spell of work; anoxæmia supervened and made him stop the exertion at a load which to a normal healthy man would be easy.

Very few malingerers were met with. They were easily detected, as they would allege a load was more than they could support before the curve had reached its crest.

BIBLIOGRAPHY.

Briggs	Physical Exertion, Fitness and Breathing.	Jl. of Physiol., 1920-21. Vol. liv, p. 292.
"	Do. do.	Jl. of R.A.M.C. 1921, Vol. xxxvii, p. 278.
Official	.. ..	Mine Rescue Apparatus Research Committee, 1918, First Report, p. 51.

CHAPTER VII.

THE BASE HYGIENE LABORATORY AT BOULOGNE.

EARLY in 1915 a fish-loft at 57, Rue du Moulin à Vapeur, Boulogne, was selected as a suitable laboratory site. By means of a partition this loft was divided into two rooms, one for chemical and bacteriological work, the other being set apart as a preparation room.

At first, as the earliest records show, only a small amount of work was undertaken. This consisted chiefly of inspection of preserved meat and other food supplies; but with the rapid extension of military operations and a corresponding increase of material of all kinds, it soon became evident that a large number of chemical and bacteriological examinations would be called for.

Steps were quickly taken to acquire the fittings, chemicals, and apparatus necessary for the work anticipated. A photograph of the laboratory, which was very well equipped for analytical work, is shown in Fig. 1. As the bacteriological examination of a large number of water samples had to be considered, as well as purely analytical work, two large incubators were installed. Large stocks of broth for the preparation of bacteriological media were prepared by the tryptic digestion of casein. Since the Boulogne water contains about 25 parts per 100,000 of carbonate of lime, a water distillation plant had to be erected. This was in continuous use, and was very efficient in supplying 10 gallons of pure water daily for chemical work.

The rooms were lighted by electricity and well supplied with window space. Owing to the very thin roof on the building, the extremes of temperature were found to be somewhat disturbing factors in summer and winter, especially in bacteriological work; but with a few modifications in the rooms these drawbacks were soon overcome. No difficulties were ever experienced in obtaining pure chemicals. The new "Jena" glass flasks, beakers, and apparatus made in England during the war proved very satisfactory. Glass stopcocks for chemical apparatus, some indicators, and certain dyes were hardly procurable after the first two years, but at no time was the

work of the laboratory impeded by the lack of any essential chemical or piece of apparatus.

The staff consisted of two officers, one warrant officer, one sergeant, and four other ranks, all of whom had previous

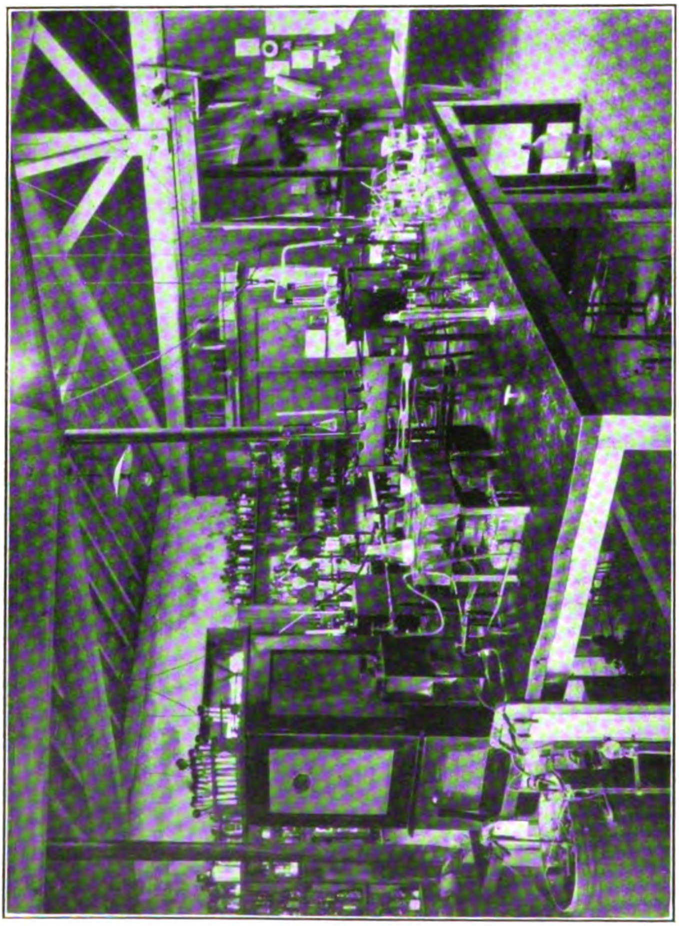


Fig. 1.—Base Hygiene Laboratory, Boulogne.

experience of chemical or bacteriological work. The average working day for officers, N.C.Os. and men was ten hours.

Work of the Laboratory.—Table I gives a summary of the routine analyses done in the laboratory from April 1915 to 11th November, 1918.

TABLE I.

Summary of Routine Analyses in Base Hygiene Laboratory from April, 1915 *to* 11*th November*, 1918.

Chemical Analyses.

Year.	Waters.		Foods.	Drugs.	Material from enemy sources.	Miscellaneous and Biochemical.	Toxicological.	Totals.
	Potable.	Boiler purposes, &c.						
April 1915 ..	78	*Nil*	134	18	*Nil*	60	2	292
1916	119	*Nil*	249	64	3	37	9	481
1917	109	15	209	38	12	31	8	422
1918 (11th Nov.)	105	18	150	60	24	45	37	439
						Total ..	..	1,634

Bacteriological Examinations.

Year.	Waters.	Foods.	Enemy Materials.	Anthrax, Examinations for.	Totals.
April 1915 ..	45	17	36	25	123
1916	261	43	42	10	356
1917	147	11	31	4	193
1918 (11th Nov.)	115	10	3	4	132
			Total ..	..	804

Most of the water samples were sent by sanitary officers. Those included under the heading "boiler purposes, etc." were forwarded by engineering units for full analysis of the saline constituents and generally for an opinion as to the treatment of food supplies prior to use.

Analyses of food-stuffs and most drugs were made for the Director of Supplies; a large number of these samples were forwarded by the Special Purchase Department, Paris.

The material derived from enemy sources was examined for the Intelligence Department of the General Staff.

Nearly all the toxicological specimens and a large number of miscellaneous samples were sent for examination by officers in charge of mobile laboratories.

No restrictions were made as to the nature of the samples which could be submitted for examination. As a result of this a very large variety of analyses appears in the records. By the acceptance of all kinds of material for chemical examination considerable interest was added to the routine work of the laboratory, and its scope became greatly extended.

Waters.—Chemical analyses of waters to the number of 411 were made to ascertain if these were fit for drinking. In all these the standard methods were employed. The scheme of analysis included the estimation of total solids, mineral matter, volatile matter, free and albuminoid ammonia, oxidizable organic matter, nitrates, nitrites, and chlorides. The chlorination figure was also determined. Poisonous metallic constituents were searched for when suspected. In only one instance was lead ever found in appreciable quantity in a sample, namely in that of an alkaline water supply at Le Tréport, which contained 0·02 part per 100,000.

Most of these water samples were drawn from sources in the north of France, and were chiefly of the "chalky" variety. The following analysis of the Boulogne water supply may be taken as representative of the type :—

Boulogne Water Analysis.

	Parts per 100,000.
Temporary hardness	23·4
Permanent hardness	2·2
Total hardness	25·6
Carbonate of lime	23·40
Sulphate of lime	0·34
Chloride of magnesium	1·21
Sulphate of magnesia	0·11
Chloride of sodium	1·62
Nitrate of soda	0·33
Carbonate of iron	Trace
Silica	0·70
Organic matter	4·50
	32·21

The total hardness of these waters was generally above 20 parts per 100,000 and due mainly to bicarbonate of lime. A notable exception was at Le Tréport, which contained practically no lime but 24·38 parts per 100,000 of carbonate of soda. Several samples drawn from sources near the River Seine contained a large amount of soluble salts, indicating filtration of tidal water ; but with these exceptions the waters examined generally conformed to the type above stated.

Bacteriological examinations were also made at the same time as the chemical analysis when the question of potability only was involved. Here, too, the standard methods were used, namely the estimation of *B. coli* content, and the determination of the total number of organisms in 1 c.c. and

0·1 c.c. on agar at 37°C. and on gelatine at 20°C. after three days' incubation. The striking feature of these examinations was the rarity with which a potable water was encountered. Many samples were found to contain *B. coli* in less than 1 c.c. Even the large town supplies, such as that of Boulogne, which was examined monthly over a period of three years, were badly infected.

That a chemical analysis alone of a water can give no absolute indication of its purity was many times confirmed. As an example of this the case of the large supply for Etaples may be cited. Repeated chemical examinations of this water were made at intervals of six weeks or two months. Only traces of free and albuminoid ammonia ever existed, together with 2·0 parts per 100,000 of chlorine. The latter figure was constantly found and there were only traces of nitrates and oxidizable organic matter. Nitrites were never present. On bacteriological examination, *B. coli* was generally present in 3 c.c. or 4 c.c.

The Boulogne town supply was also remarkably pure chemically, but with *B. coli* present varying in amount from 4 c.c. in winter to 0·2 c.c. in summer after a rainy period. A notable exception was the town supply of Hesdin, which, from the bacteriological point of view, was a relatively pure water, *B. coli* being absent in 50 c.c.

The chlorination of water supplies was therefore rightly general. There was very good reason indeed for insisting on chlorination of all water supplies in the army areas since an unpolluted water was so rarely encountered.

The peptone solution for this work was prepared in large quantities by the digestion of casein by means of pancreatin (Cole's method).

In all, 568 complete bacteriological examinations of water supplies were made during the period of the war.

Waters for Boilers and Laundries.—Full analyses of the saline constituents of water supplies to be used for steam-raising purposes were made for engineering units and laundries. All the samples submitted were, in the raw state, quite unsuitable for this purpose. The waters of the north of France contain as a rule more than 20 parts per 100,000 of carbonate of lime. This alone would be an objection to the use of the untreated water in a boiler or a laundry. If the lime and a small amount of magnesia associated with it existed only in the form of bicarbonates, the use of these waters, even in the raw state, with the addition of a small amount of soda ash might be

permissible, since the scale would remain granular and could to a great extent be easily removed from the boiler by mechanical means.

Associated with the bicarbonates of lime and magnesia, however, in almost all these waters, were small quantities of sulphate of lime particularly, and other salts of magnesia which rendered the scale so extremely dense and hard that it could hardly be chiselled from the boiler plates. Several of the scales from the boilers in use in Calais and Boulogne were obtained for examination as a matter of interest. The work of removing them from the boiler plates was extremely laborious. Their chemical composition was determined to correlate their physical characters with the saline constituents of the waters from which they were derived. Some of the scales were about half an inch thick and all were extremely dense and hard. It was therefore apparent that rapid loss of efficiency of boilers would ensue in which the untreated waters of the north of France were continually used. Many examples of this were brought to notice at the laboratory.

In laundry work the need for initial treatment of the water supplies was equally urgent. The analysis of a laundry effluent, which was discharged into a canal at St. Omer, showed that prior to the installation of a softening plant over 10 per cent. of the solids in the effluent were insoluble soaps. The damage to material repeatedly washed in the presence of insoluble soaps of calcium, in addition to the difficulty of removing these soaps when once impregnated, is considerable. The actual loss of soap in using the untreated waters, especially in such huge laundries as the army possessed, could readily be calculated from the composition of the waters. The damage done to clothing would be less easily computed but certainly would not be less serious.

From the results of the analysis of the saline constituents the amount of lime and soda required for softening purposes was calculated and stated in the reports. The waters of the north of France generally required for softening purposes the addition of from 15 to 18 lb. of lime " shell " together with from 1 to 2 lb. of soda ash per 10,000 gallons. One or two waters received for examination varied from the general type.

The analysis of a sample taken from a source (Valdilievre Well) near Calais showed a water containing a considerable amount of carbonate of lime, but in addition, large amounts of sulphate and chloride of magnesium together with chloride of sodium. This water, in spite of the lime it held, had an acid

corrosive action under high pressures, due to the decomposition of the magnesium salts which were in excess of the alkalinity. The real nature of the water was indicated in the report to the Inspector of Boilers (Northern Area) and its use for steam-raising purposes stated to be inadmissible. Owing to the shortage of the water supply, however, a mixture of four parts of Calais water with one part of Valdilievre water, treated with soda ash, was employed for a considerable time in the boilers. For some reason the Valdilievre water was subsequently used alone. Corrosion of the boiler plates resulted in a comparatively short time and was so great that the boilers had to be condemned as unsafe for further use. The results of an analysis of the Calais town supply is given in the following table to represent the "normal" type of water and to facilitate comparison. The water required 15·9 lb. lime shell (95 per cent.) with 3·1 lb. soda ash per 10,000 gallons for softening.

TABLE II.

Results of Analysis.

	Parts per 100,000.	
	Valdilievre Well.	*Calais Town Supply.*
Total solids	491·0	36·6
Non-volatile matter	445·6	32·74
Volatile matter	45·4	3·86
Temporary hardness	63·6	25·6
Permanent hardness	36·2	2·2
Total hardness	99·8	27·8
Carbonate of lime	55·4	25·6
Sulphate of lime	*Nil*	1·76
Carbonate of magnesia	6·88	*Nil*
Sulphate of magnesia	40·68	0·4
Chloride of magnesium	15·73	1·21
Chloride of sodium	315·81	2·47
Silica	8·60	1·00
Iron and alumina	2·51	0·30

In 1918 "Permutit" filters were installed at the power station, Boulogne, to soften the town water supply. The following analysis of the water after filtration is of interest in view of a harmful effect which it was alleged the treated water was capable of exercising. It was predicted that the boiler plates would become "pitted" after the water had been used for a comparatively short time.

	Parts per 100,000.
Carbonate of soda	31·89
Carbonate of lime	1·09
Carbonate of magnesia	0·29
Chloride of sodium	6·57
Sulphate of soda	1·81
Iron and alumina	Trace
Silica	0·50

It will be seen that the lime was almost completely displaced by carbonate of soda. In conjunction with the Inspector of Boilers for the Northern Area an examination of the inside of the boilers at the Power Station, Boulogne, was made eight months after the Permutit-softened water had been constantly in use. There was absolutely no sign of pitting of the plates, which were covered by a thin white granular coating of lime salts which could be easily scraped off.

The slight excess of chloride of sodium (6·57 parts) was evidently derived from the salt used in the regeneration of the Permutit, since the untreated Boulogne water contained only 1·72 parts of chloride of sodium per 100,000. Whether the preliminary treatment of such chalky waters by the soda lime process would have been more advantageous is purely an engineering question. In laundry work, the total removal of the lime by filtration through Permutit, and the consequent substitution of carbonate of soda in relatively large quantity, is a matter of less importance. The preliminary clarification of at least one of the supplies, that of the River Liane, for a laundry near Boulogne, was bound to be considered since the water at all times held a large amount of matter in suspension and could not have been run directly through a Permutit filter. It will be evident from these observations that the direct use of waters in the north of France for steam-raising and laundry purposes was rarely possible if efficiency and economy were to be maintained, and that these water supplies were as troublesome from the engineering point of view as they were to the sanitary service.

In 1918 a water-sterilizing plant was erected at Carly for the purpose of treating the Boulogne town supply. Pure gaseous chlorine, in amount exactly equal to that required for complete oxidation of all organic matter in the water, was distributed into the water mains from cylinders of liquid chlorine, a Wallace and Tiernan plant being employed. Preliminary tests were made on 26th October, 1918, when the water was treated only by day. Continuous chlorination (0·12 part per million) commenced on 30th October, 1918, at a rate of from 1·51 to

2·53 lb. chlorine per twenty-four hours. The following bacteriological results indicate how efficient the method was. No free chlorine was ever found in samples of water taken from Boulogne or from taps mid-way between Boulogne and Carly.

TABLE III.

Date.	Gelatine.		Agar-agar.		*B. coli* present in	Indol.
	1 c.c.	0·1 c.c.	1 c.c.	0·1 c.c.		
30th Aug. 1918 ..	Liq.	15	3	1	1·6 c.c.	+
29th Sept. 1918 ..	14 Liq.	6	4	*Nil*	3·3 ,,	+
26th Oct. 1918 ..	288	20	13	,,	1·4 ,,	+
28th Oct. 1918 ..	5	*Nil*	*Nil*	,,	1·4 ,,	+
30th Oct. 1918 ..	5 Liq.	,,	,,	,,	10·0 ,,	+
1st Nov. 1918 ..	2 Liq.	,,	2	,,	10·0 ,,	+
7th Nov. 1918 ..	8	1	3	,,	50·0 ,,	–
12th Nov. 1918 ..	3	1	1	,,	50·0 ,,	–
28th Nov. 1918 ..	*Nil*	*Nil*	*Nil*	,,	Absent in 110 c.c.	–

A large number of shell-hole waters were examined during the year 1918. These, however, were regarded as toxicological samples since they were generally associated with symptoms of poisoning among the troops. A large number contained arsenic. The arsenic in these was not detectable by Reinch's test and possibly existed in organic combination. It was estimated after digestion with strong sulphuric acid and reduction with sulphur dioxide by the electrolytic Marsh apparatus.

Food-stuffs.—During the period of the war 823 analyses of food samples were made. The examinations as a rule were chemical, the standard methods being employed, since the question of quality as well as that of " fitness for issue " was involved.

Preserved meats only were examined bacteriologically. It was found that a high standard in quality of food-stuffs was maintained throughout the war; comparatively few cases of rejection are on record. Samples of unsound preserved meat were occasionally sent for examination. In these samples the tinning was generally shown to be defective. In one instance —a brand of cooked ham which was issued in 5-lb. tins—the iron plate was found to be below the standard of thickness required by the War Office specification.

A large consignment of vermicelli was condemned on the results of chemical analysis in 1917. In the samples examined, the gluten was found to have been completely decomposed.

There are no cases on record of the adulteration of the commoner food-stuffs such as butters, milks, wines, and spirits.

From time to time samples of meat and vegetable rations, cocoas, dried soups, and so on, were sent for examination by medical officers with the statement that these were the cause of diarrhœa among the troops. The results of the examinations with respect to the "cause of diarrhœa" were invariably negative.

Drugs.—Of the 180 drug analyses made, the examinations in nearly all cases were called for on account of some alleged defect or impurity. In only three cases were the allegations justified.

The anæsthetic drugs, chloroform, ether, and nitrous oxide, formed naturally a large part of this total. Three samples only (ether) were found unfit for issue owing to the presence of aldehyde. No cases of impurity of chloroform, oxygen, or nitrous oxide were ever met with.

In November 1918 a number of samples of salicylate of soda, representing the stocks existing at that time in France, were examined. Free salicylic acid was found in most of these in considerable quantity, one of them containing 16 per cent. of free acid. This stock was rejected.

The remainder of the total number of drug samples examined came up to the standard of purity required by the British Pharmacopœia and called for no special comment.

A few German preparations were also examined. Among these were a 6 per cent. ichthyol in crude vaseline, used as a prophylactic against frostbite, a pure bicarbonate of soda, and four samples of calcium hypochlorite, probably used for sterilizing water or as a disinfectant. The latter contained 90 per cent. of calcium hypochlorite and about 48 per cent. of available chlorine. An interesting specimen, the possible therapeutic use of which gave rise to much speculation, found on a German prisoner of war was a gelatine capsule containing about 0·5 c.c. of refined petroleum, of low flash point.

A series of small sealed glass tubes, supposed to have been dropped from an enemy aeroplane, were sent for identification. They contained pure salicylic acid mixed with a minute quantity of a green dye.

Material of Enemy Origin.—Intelligence officers forwarded 151 specimens of supposed enemy origin for examination. Most of these were suspected to be harmful and to have been dropped from enemy aeroplanes. When the material furnished was in sufficient quantity, feeding experiments were performed

on animals kept specially for that purpose, in addition to chemical and bacteriological examinations.

No poison of any description was ever found in these samples, and no ill-effects on animals were ever observed as results of the feeding experiments. One of the specimens, found on the roof of a house in Boulogne, consisted of a packet of Blaud's pills. The greater number were chocolate sweets or cakes, sugar candy, biscuits, and other confectionery. It is possible that many of these specimens were simply accidentally lost or carelessly flung away. Usually the sweets were found in such a dirty condition that no one would have been tempted to eat them.

The usual method of procedure adopted was to test for the commoner poisons directly, such as arsenic, cyanides, and mercuric chloride; then to search for metallic poisons and alkaloids; and finally to confirm the absence of harmful agents by feeding experiments on animals. A considerable amount of work was involved in these examinations.

Much more interesting were the specimens of enemy origin sent for identification. Many of these were simple problems and the identifications were easily made. Occasionally, however, when only a small amount of material was available for examination the work was less easy, and offered some rare exercises in qualitative analysis. One of these may be recorded as an example, on account of the interest it afforded in identifying a chemical which existed only in traces in the specimens.

During the winter of 1917–18 a number of envelopes and letters were sent to the laboratory for examination. These had been posted by French prisoners of war from various German camps. The prisoners' relatives, by whom the letters were received, alleged that harmful agents were present in the envelopes, and many of these people complained of symptoms of giddiness and of faintness on opening the letters. On one occasion it was stated that a woman had been rendered unconscious by the fumes from a letter which she received from a French prisoner of war. On examination of the specimens a very faint halogen odour was generally perceptible. Chemical tests applied to the paper showed that the peculiar odour was due to the presence of residual traces of the reagent which was used by the enemy as a developer for the purpose of detecting the possible use of secret inks by the prisoners of war. All the letters were harmless.

Miscellaneous Samples.—Two hundred and eight analyses were made of samples which belonged to no particular category.

These were extremely varied in nature and their examinations were often of considerable interest. The following list of examples will illustrate the nature of this class of work :—

The examination of clothing and implements for blood stains.

Spectroscopic examination of blood for carboxyhæmoglobin in cases of suspected poisoning in mines and galleries.

The determination of the viscosity of lubricating oils for motor transport units.

The analyses of soaps and other chemicals.

The evaluation of bleaching powder for use in water sterilization and for the preparation of the solution used in the Carrel-Dakin method of treatment of wounds in animals at veterinary hospitals.

Analyses and evaluation of disinfectants.

Analyses of metals and other salved materials; paints; sewage effluents; sludges and incinerator ashes; feeding cakes; dried horse-flesh.

Some interesting analyses from the biochemical point of view were also made. The question of the possible diminution of the sugar in the blood in cases of " shell shock " was raised, and a number of samples of blood from a series of cases was selected by one of the consulting physicians. All the estimations were made by the picric acid process. The results obtained were invariably normal for blood sugar.

The absorption of picric acid and consequently the possibility of poisoning by this drug in the treatment of the extensive lesions caused by " mustard gas " were discussed in October 1918 by the Medical Research Committee. A specimen of urine from one of the fatal cases was forwarded by Colonel T. R. Elliott. A considerable quantity of picric acid was isolated from this specimen.

When the large harvest in the forward areas occupied by the enemy till July 1918 was ready for reaping, the question of the grain having poisonous properties, or at least having its germinating power affected by gas shelling, was raised. Ten samples of the wheat from Villers Brettoneux, Ville-sur-Corbie, Hamel valley and the Ancre valley were sent for examination by the Director of Agriculture. The grain and straw were submitted to careful tests for arsenic and mustard gas. No traces of these were found in any of the samples. The absence of mustard gas was confirmed by physiological tests, namely, by the application of pastes made from the grain and straw, directly

to the skin. Incubation experiments (at 30° in a moist atmosphere) showed that the grain possessed a high germinating power. No evidence was therefore obtained that the wheat had suffered in any way. A few experiments on the effects of poisonous gases on wheat grains were subsequently made in the laboratory. It was found that the germs were still active and capable of sprouting after being exposed to mustard gas for forty-eight hours in a closed atmosphere. They succumbed, however, on the third day of exposure.

An examination of a " corrosive liquid " alleged by a sergeant of the police " to be used by prisoners for rubbing on their legs and so causing admission to hospital for skin diseases," showed that the " corrosive liquid " in question was a lubricating oil. It was sterile.

Some dirty tablets picked up in the forward areas and alleged to have been dropped by an enemy aeroplane were sent for identification. The view was also expressed that the tablets were probably very poisonous. On examination they were found to consist of sodium bisulphate, the tablets used for the sterilization of water.

A sample of " white lead " supplied by a French firm to an engineering unit was sent for analysis with the object of discovering the reason for the lack of " body " and covering power possessed by the paint. It consisted of a mixture of barium sulphate and zinc sulphide.

A " brown chewing gum " found on the person of a Chinese labourer was forwarded for analysis by the dock police. The nature of this specimen which weighed 0·8 grm. was established by the isolation of meconic acid and morphine.

On one occasion a half pill was forwarded for analysis, the composition of which was regarded as important evidence in an impending court-martial. By an analysis and microscopic examination of the coating and the recognition of aloin and jalap resin in the pill mass, the specimen was identified as a well-known proprietary " liver pill."

It might be expected that old blood stains on khaki clothing would be difficult to detect by means of the benzidine test, since this reagent along with the acetic acid used in the test also gives a bluish coloration. The latter, however, is transient where no blood stain exists, and there was little difficulty in distinguishing between the colour due to the reagent on the cloth where there was no stain and the deep blue due to the presence of blood in the fabric. Old blood spots were not, however, so easily seen by the naked eye on khaki-coloured garments.

A considerable number of estimations of arsenic in urine collected from men who had been gassed were made at the request of Sir Wilmot Herringham, the Consulting Physician at G.H.Q. In many of these cases the men exhibited signs which suggested that they might be suffering chronically from the absorption of the arsenical products which were used by the enemy in shells, such as diphenylchlorarsine. The examinations of twenty-four specimens of urine from typical cases selected by consulting physicians were made as follows: 100 c.c. urine were evaporated to small bulk after the addition of 5 c.c. of fuming nitric acid and 15 c.c. of concentrated sulphuric acid, and the digestion continued in a small Kjeldahl flask till all organic matter was destroyed. The strongly acid solution was diluted with water and reduced by sulphur dioxide gas. After boiling off the excess of the latter the solution was made up to a known volume, and an aliquot part introduced into an electrolytic Marsh apparatus for the estimation of the arsenic in the usual manner. A pure cadmium electrode was used in the apparatus which had been tested repeatedly by control experiments and was found to give accurate results. Control experiments were also made with all the reagents and glassware used.

Minute quantities of arsenic varying from 0·005 mgm. to 0·03 mgm. per 100 c.c., were present in all the urines examined. It was found, however, that this quantity of arsenic did not differ considerably from that normally present in the urines of men who had been in the forward areas for some time and who had not been gassed, so that little significance could be attached to the presence of such small amounts in the urines of gassed men. Moreover, the quantities of arsenic found in the urines of men who had been a month in hospital after gassing were comparable to those found in the urines of men who had been gassed only one to two days prior to the collection of the samples. It was therefore considered highly improbable that the symptoms of chronic nerve disturbances presented by gassed men could be due to the arsenic alone.

Toxicological Examinations.—By means of an official circular issued on 28th January, 1917, medical units were informed that the Base Hygiene Laboratory would undertake toxicological examinations in case of death suspected to be due to poisoning. In this circular very definite instructions were also given regarding the removal and transport of organs, which were to be accompanied by as complete a clinical history of the case as possible, together with a full *post-mortem* report. A number

of cases of suspected poisoning was thus investigated at the laboratory during the war.

The instructions given in the circular were not always fully carried out by medical officers and pathologists who had to deal with these cases. One of the chief reasons for this appeared to be due to a lack of appreciation of the conditions which determine whether a toxicological examination is necessary or not. The result was that some of the material submitted for examination was sent without any definite reason on the mere supposition that poison might be involved in the cause of death.

Out of a total of 56 examinations, 28 were made during the last year of the war. The usual scheme of analysis was followed, namely, the search for (1) volatile poisons, (2) metallic poisons, and (3) alkaloidal and other organic poisons.

A physical examination of the stomach contents was first made and the general characters noted. After excluding the presence of such toxic agents as mineral acids, alkalies, arsenic, and cyanides, one-third of the stomach contents was distilled after being rendered acid with tartaric acid and the distillate tested for cyanides, alcohol, chloroform, and so on. The residue in the flask was then rendered alkaline with carbonate of magnesia and redistilled, the distillate being again examined for chloroform and volatile bases, such as nicotine.

In a large number of the cases in which alcoholic poisoning was suspected alcohol was found in the stomach contents. No other volatile poison was ever isolated. The percentage of alcohol found in the stomach contents was determined from the specific gravity of the distillate after making the latter up to a known volume and filtering off fat and fatty acids. No fewer than fifteen such examinations were made in the months of December 1917 and January 1918, and the greatest number during the Christmas and New Year week.

In these cases there was a certain uniformity in the character of the stomach contents which is perhaps worthy of note. As a rule a large amount of food-stuff was present in an undigested state. Nearly 600 grm. were found in one case. The large masses in which the food-stuff existed suggested that it had been "bolted" and that very little vomiting had occurred. The smell of alcohol was always evident and the stomach contents and viscera were not decomposed. The alcoholic content varied considerably; the amount present probably depended chiefly on the length of time elapsing between the onset of unconsciousness and death. In one case in which

the stomach contents weighed 289 grm., 116·5 grm. of alcohol were present. More often, the alcoholic content was between 2 per cent. and 3 per cent.

Very little significance could be attached to the finding of alcohol in the stomach contents when there was no clear history of excessive drinking and probable alcoholic poisoning.

Inorganic Poisons.—An aliquot part of the stomach contents and mashed viscera was subjected to a Fresenius digestion (potassium chlorate and hydrochloric acid) to destroy organic matter, and metallic poisons searched for in the usual manner. A separate small quantity of the stomach contents was examined for the presence of arsenic, after a Kjeldahl digestion and reduction with sulphur dioxide, by means of the electrolytic Marsh apparatus, in which a pure cadmium electrode was used.

Some cases of metallic poisoning were investigated. In one, that of a soldier who had gone into a veterinary hospital and taken what he unfortunately regarded as a " dose of salts " from a cupboard, 0·041 grm. of mercuric chloride were extracted from the small amount of the stomach contents available for examination. The poison was also found in the small intestine. The tissues of the viscera showed the extreme " fixing " effect the mercuric salt had had. The isolation of the salt presented no difficulty.

The stomach of a calf which had died in suspicious circumstances was sent for examination by a veterinary unit, an irritant poison being suspected. Lead was isolated. One or two small pills picked out from the stomach contents were found to consist of lead carbonate. How the poison had been administered was not known.

The stomach of a cow belonging to a French farmer was found to contain a large quantity of pure tinfoil. The farmer alleged that his animal had been poisoned by calcium carbide or chloride of lime, which had been left in the fields by an army unit.

One case of arsenical poisoning was of interest ; it was typical of a number. Three soldiers in the forward area had drunk some tea made with water from a certain shell-hole. They immediately became very sick and vomited ; but after a short period of illness all recovered. A sample of the shell-hole water, the tea, and the vomited matter were forwarded for examination for poisons. Arsenic in considerable quanity was isolated from each of the specimens. The shell-hole water contained 12 mgm. (As) per 100 c.c. A large number of samples

of water from shell-holes in the forward areas were examined from time to time. Many of these contained arsenic in large amount.

A remarkable series of cases of arsenical poisoning occurred among the inhabitants of the town of St. Amand. About the middle of November 1918 many people in the town became suddenly ill; some deaths were reported. The bread made at one of the local French bakeries came under suspicion. Samples of flour and bread taken from the French bakery were sent to one of the mobile laboratories for examination by the medical officer in charge of the sick, ergot in the flour being suspected as the cause of the illness. These samples were forwarded from the mobile laboratory for examination on 20th November, 1918. No signs of ergot being found in the flour or bread other poisons were sought for. None was found in the French flour, but the bread contained 0·91 per cent. arsenious acid. On 25th November all the materials used in bread-making at the French bakery were sent for examination. No arsenic was found in the water or salt used, nor in the flour. A considerable quantity of arsenic, however, was present in one sample of mouldy flour. Arsenic was present in almost all the samples of bread submitted, and in one to the extent of 1·24 per cent. As_2O_3. How the arsenic was introduced into the flour, and from what source the latter was derived, were never ascertained.

Organic Poisons.—In the search for organic poisons Witthaus' modification of the Dragendorff scheme was usually employed. The stomach contents and mashed viscera were extracted with alcohol after acidifying with tartaric acid, and the alcoholic extract evaporated to pastiness *in vacuo*. Absolute alcohol was then gradually added till all gummy matter was precipitated in granular form, and the mixture allowed to stand twenty-four hours. The alcoholic solution was filtered off and again evaporated to a syrup under reduced pressure, the residue "taken up" with water, filtered, and the extraction with the various solvents proceeded with in a continuous liquid extraction apparatus. Any residues obtained on evaporation of the various solvents were then examined for alkaloidal and other organic poisons. Control experiments with mixtures of pure alkaloids and mashed tissue were performed to test the efficiency of the liquid extraction apparatus used. This apparatus which was improvized by modifying a large Soxhlet apparatus was found to be very convenient and useful. Acetic ether was invariably employed as the solvent for morphine in preference to amyl alcohol.

Two cases of morphine poisoning were met with. In both there was a clear history that this alkaloid had been taken. In one case some tablets which were found near the bedside of the deceased were sent for identification along with the stomach contents and viscera. These tablets proved to be morphine tartrate (¼ gr.). 2·8 gr. of morphine were isolated from 92 grm. of the stomach contents.

In the other case, two chemical specimens were sent for identification along with the viscera. One of these was a small bottle containing about 20 c.c. of eucalyptus oil; the other, a white powder, weighing 0·147 grm., was found to consist of pure morphine tartrate. Only a minute quantity of morphine was isolated from the stomach contents and available viscera in this case.

In the summer of 1918 a series of outbreaks of poisoning among horses occurred, and the feeding cake which was extensively used in the veterinary units came under suspicion. On 6th May, 1918, two samples of linseed cake, one taken from the manger of a horse which had died, the other representing an average sample of the stock of feeding stuff on hand, were examined at the request of the Director of Veterinary Services. The compositions of the two samples were almost identical, the results of the analysis being as follows:—

Moisture	12·12	per cent.
Ash	5·50	,,
Sand	1·80	,,
Oil	5·90	,,
Woody fibre	8·05	,,
Albuminoids	29·94	,,
Carbohydrates (by diff.)	36·69	,,
Iodine value of oil	140·00	,,
Free fatty acids in oil (as oleic acid)	28·00	,,

This feeding cake was unsatisfactory in two particulars. The amount of sand it contained was unduly high, and the proportion of free fatty acids in the oil indicated that considerable changes had occurred in the latter, probably from long storage.

Attention was then turned to the character of the oil. A large quantity of the sample was extracted with ether and the oil critically examined, special attention being paid to the iodine value, which was found to be considerably lower than that of linseed oil (160·0). The oil, moreover, was non-drying. The possibility of the linseed cake being contaminated with crushed castor seeds suggested itself, and a large fresh sample was further treated in the following way: 50 grm. of the crushed

linseed cake were introduced into a Kjeldahl flask with about 500 c.c. of 2 per cent. HCl. The flask was connected to a steam generator and steam bubbled through the mixture for one hour. A low Bunsen flame under the Kjeldahl flask served to keep the volume of the liquid in the latter constant. The contents were then filtered off through muslin. The residue on the filter after being washed thoroughly with boiling water several times was transferred to the Kjeldahl flask previously used, mixed with about 500 c.c. of 2 per cent. caustic soda, and again steam-heated for one hour as before. The alkaline liquid was filtered off through muslin and the residue of woody fibre, thoroughly washed with boiling water, was finally transferred to a beaker and bleached by means of an excess of a strong emulsion of chloride of lime and water. An examination of the woody fibre at this stage showed that among the mass of light-coloured bleached residue there existed a number of small black and dark brown particles, with ragged edges. These were picked out. They were found to be extremely hard and brittle, and could only be crushed with difficulty. Microscopic examination of the crushed fragments showed the characteristic boomerang-shaped cells of castor husk, the presence of which was confirmed by the discovery of the peculiar mottling on the surface of some of the larger pieces.

Feeding experiments were made on animals during the chemical search for poisonous substances in the linseed cake. A rabbit was fed on a small quantity (about 10 grm.) mixed with bran. After a period of dulness and depression associated with profuse diarrhœa, the animal died. A *post-mortem* examination showed a very extensive hæmorrhagic enteritis extending to the colon, which was filled with dark-coloured blood. Blood cultures were sterile.

After the discovery of castor husk in one stock of linseed cake, all the supplies of feeding stuffs in France were critically examined. The examination of twenty-one average samples of linseed cake and copra cake was begun on 1st June, 1918. Four samples of linseed cake were found to contain a considerable quantity of castor husk. The stocks from which they were derived were condemned as unfit for issue.

On 20th June, 1918, twelve additional samples were submitted and five found to contain castor husk. The amount of cyanogenetic glucoside in all these samples was also estimated as a matter of interest. The cake, however, had always been given to the animals in the dry state. The amount of glucoside found was never above the average.

Subsequent investigation showed that all the contaminated stocks of linseed cake were of Spanish origin, and that they had been pressed by machines which were used for treating castor beans. The presence of the castor husk in the linseed cake was possibly due to carelessness. The death of many valuable animals was the direct result.

On 11th September, 1918, the veterinary staff of a cavalry division forwarded a horse's stomach and intestinal contents together with a sample of water from the pond where the animals had been watered. The following short history of the illness of the animals was also given :—

"Sixty animals from an artillery battery went off their feed. On taking temperatures they were found to be from 102° to 105°. Five animals were very ill and one has died. The symptoms were—temperature, colicky pains, frothing at the mouth, and congestion. *Post mortem*.—All normal except lungs, which were very congested. Poisoning is suspected, probably 'gas.'"

The pond water was quickly examined for arsenical and other poisons. None was found. No traces of "mustard gas" were present. The stomach contents were seen to consist of partially digested food-stuff mixed with a considerable amount of small dark pieces of castor husk. The amount of castor husk in the stomach contents was then estimated quantitatively : 1·7 per cent. was present. A large amount of the husk was picked out from the intestinal contents, which were slightly blood-stained. From the comparatively large size of some of these pieces—many of them showed plainly the characteristic mottling as well as a spherical curvature—it was considered extremely probable that whole castor beans had been given to the horses. This was subsequently found to be the case.

In the report sent to the division it was pointed out that the *post-mortem* findings did not contain any reference to the intestinal and renal changes which are so characteristic of ricin poisoning. The following note was received from the division a few days later : "In the first *post-mortem* examination there were no intestinal lesions, but *post-mortem* examinations of nine other horses that died showed hæmorrhagic enteritis." The horses had been fed on oats which had been mixed with whole castor beans, the contamination probably occurring at the docks during the unloading of a mixed cargo.

It is interesting to note that three separate cases of ricin poisoning among French horses, occurring within eight days,

were recorded in the *Matin* of 4th May, 1918. The explanation given was that the contamination of the oats by castor beans had been caused by the carelessness of coolies who unloaded the cargo mixing castor beans with the oats.

Attention was drawn to the necessity for a careful scrutiny of all food-stuffs intended for animals, and a description of the whole castor bean was given, to facilitate identification of the latter, in a General Routine Order issued after these cases of poisoning had occurred.

The lack of care in avoiding contamination by castor beans during the manufacture of linseed cake resulted in such a serious loss of animals that samples of all the supplies of Spanish feeding cake were subsequently sent to the laboratory for examination before the stocks were issued. A very large number of these were found to contain castor husk and were condemned.

A sample of a yellow crystalline powder was received from a mobile veterinary laboratory on 17th November, 1918. Several horses which had died were suspected to have been poisoned by this material. Unfortunately, no history of illness or results of *post-mortem* examinations could be elicited. On chemical examination the powder was found to be an organic nitro-derivative of the benzene series, which was probably used for blasting purposes. No stomach contents, urine, or viscera were sent for examination.

One case of carbon monoxide poisoning was investigated, that of a sapper who was found dead at the bottom of a deep well in which he had been working. The appearance of the body at the *post-mortem* examination suggested carbon monoxide poisoning. The blood presented the typical pink colour, and on spectroscopic examination carboxyhæmoglobin was identified. The blood expressed from the lungs and kidney was also characteristic; that from the liver was less so, though a faint pink colour was still noticeable on dilution.

Preparation of Gum Saline Solution for Intravenous Injection.—In the year 1918 a large amount of additional work was involved in the preparation of a sterile gum saline solution for intravenous injection. A considerable amount of experimental work on the best means of preparing such solutions had been previously done in the laboratory during the winter of 1917, and the results of the experiments were stated in a report to the Medical Research Committee. The laboratory was then asked to undertake the preparation of a solution on a large

scale for distribution in the forward areas in the treatment of "shock."

A 6 per cent. solution of gum acacia in 0·9 per cent. of sodium chloride was decided upon. Further experiments were conducted on a large scale to discover the most efficient means of sterilization. Many difficulties were encountered in what seemed at first a comparatively easy task, especially with regard to the process of sterilization and the production of a clear solution.

It was found, for example, that the methods usually adopted for sterilization were not applicable, and also that sedimentation of solids from the colloidal state was very prone to occur during sterilization and thus render the solution unfit for use.

The process finally evolved was satisfactory and was fully described in a report to the Medical Research Committee, by whom it has been published.*

A special plant was erected in June 1918 for the preparation of the solution on a large scale. Four men, each working eight hours daily, were employed solely on the preparation, and an average daily output of 75 litres was maintained. The supplies were transported to the forward areas in motor cars.

Fig. 2 serves to illustrate the process of preparation, which may be described shortly as follows :—

The gum acacia was weighed out together with the requisite amount of salt and a solution of fourfold strength prepared. This was then diluted to the necessary concentration with boiled tap water and the solution, contained in enamelled pails, was heated in a Barford and Perkins pressure sterilizer at 120° C. for one hour. The pails were removed and the precipitated mineral matter filtered off through cotton-wool contained in large enamelled iron funnels into glass reservoirs. This filtration removed the greater part of the precipitated mineral matter. The solution was then filtered under pressure through a series of tiers of fine linen and filter paper contained in Buchner funnels ; and finally, to ensure that all traces of solid matter were removed, it was passed through a single layer of filter paper.

The solution was then ready for sterilization in the Barford and Perkins machine. Specially made bottles, fitted with spring clip stoppers and similar to milk bottles, were filled with the clear solution and a specially devised air filter was fitted to each. They were sterilized in the chamber of the machine in batches of sixty by heating for one hour at a pressure of

* M.R.C. Spec. Rep. Series, No. 25.

15 lb. per square inch. After cooling the bottles were stoppered under aseptic conditions and sealed off under a layer of melted paraffin. Samples were selected from each batch for incubation on agar plates to ascertain that sterilization had been complete.

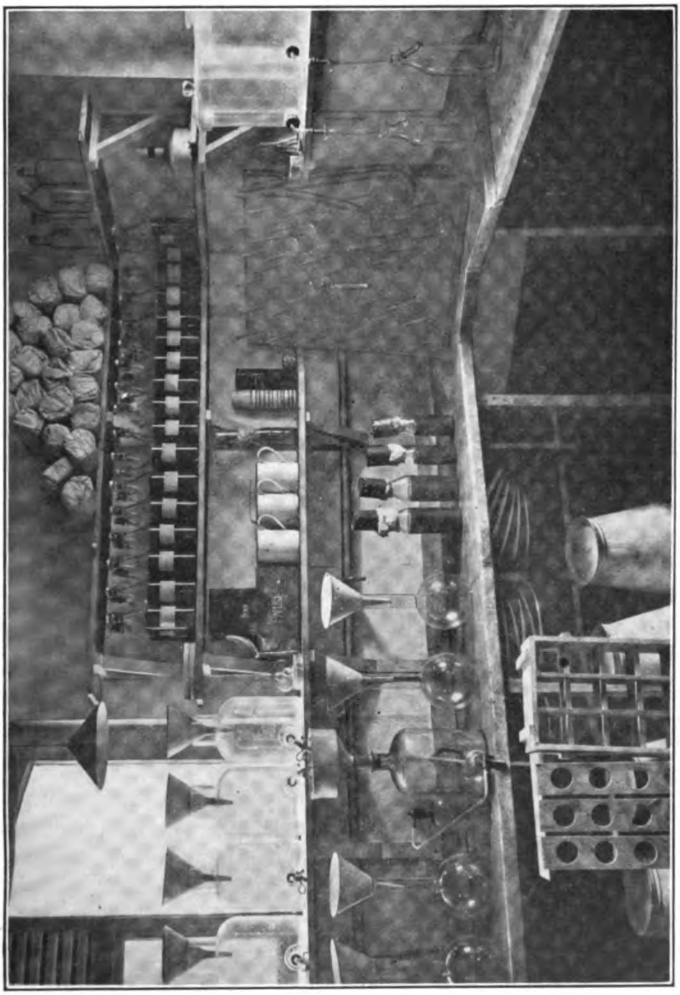


Fig. 2.—Apparatus for the manufacture of sterile gum infusion fluid, Base Hygiene Laboratory, Boulogne.

The bottles were then labelled, packed in specially made boxes, and transported to the advanced depôt medical stores by car for distribution.

The solution so obtained was sterile, of a light yellow colour and faintly opalescent when viewed in bulk. Its reaction was nearly neutral (P.H. 7·7) or just on the alkaline side of neutrality. Its viscosity at 37° C. was 1·88 times that of water. The bottles in which the solution was contained were used as reservoirs during the injection.

During the summer of 1918 about 5,000 litres of sterile gum acacia solution were despatched to the forward areas and a large amount was also supplied to the base hospitals.

CHAPTER VIII.

PREVENTION OF MALARIA.

MALARIA has been notoriously a scourge of armies not only in tropical and sub-tropical but also in temperate climates. The records of history indicate, if somewhat vaguely in ancient times, that malaria accompanied the movements of armies throughout Eastern and Central Asia, India, Mesopotamia, Asia Minor, Africa, Macedonia, Greece, and Italy. In more recent times accounts are more definite and show that malaria seriously interfered with many military operations during the past two centuries, while during the war of 1914–18 on army fronts in Macedonia, Palestine, Mesopotamia, and East Africa it became a serious factor. While the latitudes, within which it is endemic, are mainly tropical and sub-tropical, it may, under the stimulus of wide movements of those infected, extend far into temperate and even to sub-arctic regions, where normally it does not occur. It was to be expected in Africa, Mesopotamia, Palestine, and Macedonia, though its volume was intensified by abnormal local accession to the population ; but cases also arose in France, in England, in Northern Russia, in America, and in South Africa, temperate lands where it had been regarded as abolished and not likely to recur.

Of the various factors which combine to cause malaria, the physical features of a country are of primary importance, as other factors depend greatly on these. An elevated chalk down or arid sandy coast or agricultural country intensively tilled and with thorough subsoil drainage will in no latitude become a malarial endemic area. But swamp land on a coastline or inland, river valleys, alluvial plains, marsh land with stagnant water, agricultural land under poor cultivation and ineffectively drained, bush country and jungle, woodland and forest at various elevations and with areas of still water or sluggish streams, are typical regions of endemic malaria. Even in arid deserts, with widely separated oases, and in dry barren country where artificial wells are the only source of water, malignant malaria is well known to be a scourge. Cities are generally exempt from malaria, while their suburbs may be gravely infected. The disease is essentially a disease of country as distinct from town. Elevation alone probably does not affect the occurrence of malaria, but elevation is generally accompanied by change in those physical features and conditions of

temperature which prevent malaria. But in certain tropical situations malaria occurs at a height of 6,000 ft., and the disease is found below sea-level in the valley of the Jordan in Palestine.

While the physical features of a country are a certain indication of its malarial potentiality, no safe regional generalization may be made without intimate local investigation. For instance, in general it might be asserted of the arid lands of Palestine and of the Sahara Desert that they are not malarious. Nevertheless, the presence of innumerable mosquito-infested wells in the one region and of scattered oases with swarms of mosquitoes in the other, make them equally as dangerous as a country more obviously adapted by nature for the production of malaria.

Conditions in War Areas.

The region of Eastern Europe may be accepted roughly as referring to the whole Balkan Peninsula, Roumania, Bulgaria, Serbia, Rumelia, and Turkey. Malaria contracted in Eastern Europe has been generally spoken of as having been acquired at Salonika, as the district around that city formed the military base for the British troops. The fevers of these parts were known historically and their occurrence was anticipated by the medical authorities during the war. The malarial conditions were chiefly around the courses of rivers, in wide valleys where swamps were frequent and extensive, in the neighbourhood of lakes whose broad, shallow margins were marshy, and along the shores of the Ægean, the Caspian and Black Seas, wherever swamp and lagoon existed. Elevation in itself was no bar to the occurrence of malaria in these regions, except when accompanied by remoteness from the more immediate physical factors favourable to mosquito production. Monastir, for instance, at an elevation of 2,000 ft., was free from malaria, but the same country in its lake borders at considerable elevation produced a high malaria infection. Anopheline mosquitoes were recorded in Macedonia at a height of some 4,000 ft., but it did not follow that at that elevation malaria would occur. The deciding factor then was temperature. Independent of meteorological influence the main factor in the production of malaria in Eastern Europe is the configuration of the country, its lakes, streams, wide valleys with sluggish water-flow and extensive alluvial and maritime swamps. The result is an abundance, widespread if not continuous, of water of a depth most favourable for mosquito breeding, and with

aqueous and subaqueous vegetation eminently suited to the needs of anopheline mosquitoes. Naturally and actually the intensity of infectiousness of the country was modified by elevation, but no absolute generalization in regard to elevation and freedom from infection could be made with safety.

Malaria was reported from Petrovsk on the Caspian Sea. In Transcaucasia, the swampy Black Sea coast is malarious, as also are the alluvial valleys and plain of the Araxa and Kur Rivers, and the swampy margins of the Caspian Sea. The malaria records of certain situations, obtained from inspections during the years of the war, showed that Borjous, Akhaltsikh, Akhalkalaki, Kars, Shosha, Artvin, Quharvarshana, and Krasnovodsk were non-malarial districts; while malaria existed in Agdon, Poti, Borchka, Ardanouch, Petrovsk, Nakhishevan, Davalu, Baku, Tiflis, and Alaverdi.

Malaria occurred amongst the troops in Transcaspia and Persia, and this region is generally considered a home of endemic malaria, although different reports emphasized the comparative absence of malarial conditions from the area lying between Kurdistan and the Caspian.

On the course of the Euphrates and Tigris there are malarial conditions, discontinuous in area, throughout Mesopotamia. The sources of mosquito-breeding are irrigation channels and gardens, temporary swamp ground formed by irrigation methods and by overflow, the borders of permanent marsh, and the *wadis* in the low hill ranges. Situations specially indicated as malarious were Diyala, Ba'quba, Qarrah Tappah, Kifri, Tuz, Imam, Sima, Shahraban, Sermil, Sekharidza, Harir, Chasma Safed, and Diwaniyeh. Everything pointed to extensive malarial conditions, which more intensive cultivation, if not controlled by malaria experts, would increase.

On the whole the desert condition of Arabia prevented malaria, but from the various reports it appeared that wherever there was an oasis or a stretch of irrigation, virulent malaria was found. Thus the whole extent of the eastern coast of the Red Sea was malarial. Malaria existed at Shaikh Othman, in the stretch of irrigation land extending along the railway line some 30 miles from Aden, and in Hodeida, Bajil, and Yemen. It was present in the innumerable *wadis* wherever there was perennial water and on practically all oases throughout Arabia.

Amongst the troops operating in Palestine, Syria, Asia Minor, and Sinai malaria was fairly extensive and general. These regions form four or five different types of country which have all in lesser or greater degree shown malaria incidence.

There is first an extensive coastal belt on the Levant, of rich alluvium, well cultivated in parts and well populated. It extends inland for varying distances from approximately 5 to 40 miles or more. Fruit gardens are numerous and other cultivation is general. Irrigation alternates with swampy land and marshes. Malaria abounds along the river valleys, swampy coastline, in irrigation land, and in fact wherever human habitations are collected around rich cultivation.

Beyond this belt of alluvium a zone of foot-hills extends from north to south, which in spite of being generally a zone of arid, bare limestone masses, shelters wells, deep *wadis*, reservoirs, and irrigation plots, productive of malaria wherever the cultivators and herdsmen dwell. Thus the valley of the Auja was a source of malaria amongst the troops. The Great Valley of the Jordan, with the surroundings of the Dead Sea and Sea of Galilee, formed a distinctive region, in which innumerable watercourses presented malarial conditions below sea-level. Mountainous country rises behind the foot-hills, some 3,000 ft. high on the average in Palestine, as around Jerusalem, but in the north the land rises to elevated ranges of 8,000 to 11,000 ft. in height in Lebanon, and to extensive plateaux and ranges of still greater height in Asia Minor. Evidence of malaria in the higher mountainous country was scanty, nor was the population sufficient to make it felt; but in the hills of Palestine, in the neighbourhood of villages surrounded by wells and reservoirs, the disease was common.

The Black Sea border of Asia Minor has much swampy coastline, which is notoriously malarious; the Ægean and Levant coastlines are less so.

From the hills to the east and south, the region of Palestine and Syria merges into desert, on the irrigated hinterland of which, behind Jordan and Lebanon, malaria is still to be found. In the Sinai district in the south, in *wadis* in the hills, in the neighbourhood of the Suez Canal with its lakes and swamps, on all oases, and in fact wherever water is to be found, especially where accompanied by irrigation, there malaria exists.

In Egypt malaria was met with, but there was no evidence of any serious extension of the disease within the country. The malarial conditions in the Nile Valley of Lower Egypt were limited to irrigated and occasional swampy ground. In the towns of Alexandria, Port Said, and Cairo malaria was rare. In the Valley of the Nile in Upper Egypt malarial conditions accompanied swamp, irrigation, and cultivation. In the desert,

including the Arabian desert and the Sahara, every oasis may be regarded as infested with mosquitoes and infected with malaria wherever irrigation and cultivation are carried on.

In German East Africa or Tanganyika much malaria occurred during the war, but there was little record of malaria in German South-West Africa. In other parts of Africa except South Africa malaria existed. On the coastline from Delagoa Bay about latitude 26° S. it was very prevalent, but in the interior, in latitudes south of the Tropic of Capricorn, the disease was not much in evidence except along the river valleys. When South African troops, infected in other regions, returned to these parts, precautions were taken to ensure a maximum reduction in the number of malaria carriers.

As to the physical features of the malarious regions of East and West Africa somewhat similar conditions prevailed in all. The country rises in terraces from a littoral of widely varying width, consisting of alluvium, swamp, and sand of varying extent. Alluvium and swamp are typical of the east coast, especially around the many river-mouths. Sand characterizes a great part of the south-western coastline, while alluvium, swamp and lagoon are typical of the territories bordering on the Gulf of Guinea. Beyond the coastline hills rise in terraces; in some parts mountains of great elevation quickly dominate the coastal zone; in others the rise to the central elevated plateaux is more gradual.

Rainfall on the east coast is abundant and excessive from a few degrees south of the Equator, while on the west coast, from Cape Town to a latitude of about 8° S., just south of the mouth of the Congo, rainfall is slight. A bare and sandy coastline consequently is the predominant feature on this south-west coast; and malaria, with local exceptions such as in the swampy neighbourhood of Benguela, was not common. On the east coast from Delagoa Bay northwards to the Equator, especially about Sofala, Mozambique, and Zanzibar, the conditions were typically malarial, extending inland along the great river valleys.

The prevalence of malaria in the territories extending from the Gulf of Guinea inland around the great Rivers Congo, Ogowe, Niger, Gambia, and Senegal was well known, and malaria was extensive amongst the troops operating in the Cameroons.

With regard to the Pacific provinces of Germany and Australasia, malaria had recently been brought by soldiers

from the German Pacific islands. Australia and Polynesia had been credited historically with comparative exemption from malaria. Bare arid country characterized a great part of Australia within latitudes where otherwise malaria might be expected; but within these desert districts malaria was known to occur at mining and other settlements, but apparently in endemic form attacked the native population only. In New Guinea malaria was endemic, the physical conditions there being wide alluvium, swamp, lagoon, marsh, and partial cultivation.

In the smaller groups of the Pacific islands anopheline mosquitoes were reported to be widely distributed, although the islands have been reputed to be remarkably exempt from malaria.

The occurrence of indigenous malaria in parts of Europe where malaria was not normally endemic has been recorded during the war. In Northern Italy and in Southern Italy, where malaria normally occurs, its incidence extended to districts where its occurrence was previously rare. In France, Belgium, Russia, and England the disease also occurred indigenously during the war.

The conditions in all these countries have been the great importation of carriers and the presence of anophelines. The latter was determined in all places by typical physical features. In England the centres of infection were the areas of marshland, especially in Sheppey and around Sandwich in Kent. Of less extent, infection occurred in the Fen Country, in Norfolk, Suffolk, Essex, and Hampshire. Isolated cases also occurred in other parts of England south of the Humber. None were recorded in Scotland or Ireland or in England north of the Humber. The marshland, where most of the cases occurred, was intersected by dykes of water which were practically stagnant throughout the summer and overgrown with surface and subaqueous vegetation, and which usually had a deep bed of ooze. These conditions were specially suitable for the breeding of anophelines and in some districts *Anopheles maculipennis* swarmed in enormous numbers. While malaria might have been expected to be equally as frequent in Essex, Suffolk, Norfolk, and Lincoln as in the marshlands of Kent, especially on the Thames estuary, the association of habitations with malarial conditions was not so close in these former counties as in Kent. Marshland and malarial conditions were restricted to comparatively narrow valleys winding among higher ground of sand and gravel. An exception to this was

along the immediate coastline of Essex on the Thames estuary, but there was either no cultivation or no habitation in the marshlands; or the marshland was not intersected by fresh-water dykes, and was only indented by salt-water or brackish creeks; or, as was the case higher up the Thames, there was more subsoil drainage. In Lincolnshire, again, the dyke system was well controlled, the dykes were deep and over-shadowed by high banks, and undrained marshland was rare or remote from habitations. In fact, in England in those situations where malaria occurred inland, the presence of stagnant water with abundant aqueous vegetation in dykes, ponds, canals, and lakes has been constant.

Similar physical features existed where malaria was prevalent in France and Belgium.

In Italy, swamp and casual water, giving rise to anopheline breeding, existed around the rest camps in Taranto.

In Russia, the Don valley and the Caucasus were regions of endemic malaria, but cases of infection also occurred at Archangel, where the association of pools and swampy ground with the presence of *Anopheles maculipennis* was recorded.

Most of the islands of the West Indies possess the physical features which determine malaria, and an average endemic infection on different populations of from 20 to 40 per cent. of the inhabitants was ascertained. Lagoons, swamps, and ill-drained alluvium, kept in moist condition by reefs and bars off river-mouths, were typical of the coastline. In the interior of the infected islands, river valleys with undrained swamps, margins of lakes, irrigation land and gardens were the main sources of infection. But casual water around dwellings was also in many situations the cause of the malaria and of seasonal epidemics.

During the years of the war, blood examination of men recruited in the West Indies was undertaken with a view to selecting healthy men only, and at the same time limiting the spread of malaria to other countries by malarial carriers. In Santa Lucia the temporary occupation by troops led to the adoption of local measures of prevention, where conditions of swamp and casual water were productive of malaria.

The movement of troops within and beyond the American States is said to have transferred malaria infection from one area to another. In the United States of America a general defence against the internal transportation of malaria and its importation from outside was organized.

The natural features in the United States and in South and Central America which determined the occurrence and distribution of malaria were similar to conditions elsewhere.

Amongst the records of malaria cases in the theatres of war and in commands in England, not a few referred the infection to India, where the physical features, temperature, and systems of irrigation and watercourses are well known and typical of a malarious country.

In Hong-Kong around military quarters, malarial conditions, due mainly to untreated gullies in a natural state of stagnation and vegetation, exist to a certain exent, and there were records of malaria infection there. Elsewhere throughout China both on the sea-coast and inland malaria exists, but its extent did not appear in the records of the war.

Seasonal and Meteorological Factors.

The relation of malaria to meteorological and seasonal factors was not very clearly exemplified during the war in tropical climates. Conditions of temperature might be more or less equable throughout the year and thus sufficient to maintain a continued infection. The main meteorological factor affecting the incidence of malaria and determining its epidemicity in these situations was rainfall. In a country where mosquitoes abound the whole year round and the temperature is favourable for their existence, rainfall is responsible for the rapid dissemination of malaria infection, not merely by increasing the number of mosquitoes but by extending the area over which breeding may take place. Thus, casual pools intimately associated with human habitations became infested with mosquitoes, and their proximity to the habitations facilitated the transference of infection from house to house. In the majority of cases rainfall occurs at a definite season of the year, and thus in the tropics a definite season is recognized as one in which to expect an outbreak of malaria.

In temperate climates the dependence of infection on season is still more obvious. There is cessation of infection in the cold winter months, and the season of epidemic rise depends on the relative length of winter and summer. A certain temperature is necessary to allow mosquito development; and also a certain temperature is required to ensure infection from the full development of the protozoal infective organism within the mosquito. Temperature and rainfall then are factors of importance in fixing the season of malaria occurrence;

and a careful observation of their records is essential for successful anti-malaria operations.

But many interesting points in regard to temperature in its relation to malaria have still to be determined. The definite maximum, minimum, and optimum temperature at which in natural conditions the development of the anopheline mosquito takes place has yet to be ascertained for different countries; and it has yet to be established whether in the tropics continuous breeding of all species goes on the whole year round or whether there is a period during which breeding ceases, independent of the existence of suitable breeding places. Investigations on these lines are needed in order to be able to fix the date of expectancy of an epidemic outbreak and to take preventive measures accordingly in different latitudes and years.

It is probable that the period of incubation of the protozoa within the mosquito varies with latitude, which means temperature. A geographical limit is recognized beyond which in either the northern or southern hemisphere indigenous malaria does not occur under natural conditions. This geographical boundary is represented by an isotherm of 59° to 60° F.; and further, the mean temperature of about 60° F. must be maintained for about sixteen days to allow the establishment of malaria infection. The mean temperature of 60° F. may be arrived at by a varied combination of maxima and minima, continuous and discontinuous. There is no evidence that temperature of the air affects the receptivity of man for infection.

The relation of temperature to the sexual development of the different protozoa of malaria is evidenced probably in the season of incidence of the different infections. It was found that the commencement of *Plasmodium vivax* infection preceded the *falciparum* infection by about a month under conditions of normal temperature and the maximum incidence of the latter was about two months later than the former. The season of incidence of *Plasmodium malariae,* the quartan infection, was not determined. Again, in temperate countries where endemicity is not established but where imported carriers may set up infection, the only parasite discovered during the war among genuinely indigenous infections was the *Plasmodium vivax,* the benign tertian parasite.

These occurrences point to the association of different temperature conditions with the development of the sexual stage of the malaria parasites in the mosquito. Extended epidemiological observation, however, is needed, as well as laboratory

experimentation, to enable conclusions to be drawn. For the purpose of preventive measures, especially in a country where malaria is not endemic and which is subject to imported infection, definite information on these points is of much importance.

Some facts, however, concerning seasonal and meteorological factors, both from laboratory work and epidemiological observations as affecting the different countries in which military operations were carried on during the war, have been recorded.

The temperature relations of malaria in the British Isles are interesting in view of the historical and traditional accounts of malaria in past times, no less than on account of the occurrence of malaria infection in England during the years 1917–19 in parts of the country from which the disease seemed to have long disappeared.

The question of endemicity of malaria in the British Isles is of considerable interest. There is much evidence of the occurrence of malaria in England in the past, but there is no sound evidence of its continuity over a long period up to about sixty years ago. There is, however, evidence of malaria having occurred at irregular periods.

Sixty years ago and more it was fairly extensive in England, especially in the marshlands of the Thames estuary, and the outbreak was associated with the return of ague-infected troops from the Balkan peninsula during the Crimean War. Movements of armies are associated also with other periods of malaria occurrence in England. But since 1860 malaria has been practically unrecognized in England, although there is evidence of the occasional occurrence of individual cases. There is, however, no evidence of continuity of infection.

The years 1856–59, during which the last extensive occurrence of malaria in England is recorded, comprise a sequence of years of high temperature above the normal and long continued in each year. Over these four years there was an average increase of about six weeks in each year in which a mean temperature of 59° to 60° F. continued. The obvious lengthening of the infective period and shortening of the winter period of recovery from infection consequently caused epidemic occurrence of malaria in these years. The year 1860 which immediately succeeded was phenomenally cold. In no month was the mean temperature of possible protozoal development maintained. As no fresh malaria infection occurred in 1860, there would thus be few carriers to produce fresh

infection in 1861, and the traditional and recorded suddenness of the disappearance of malaria from England is thus explained.

Under normal conditions of temperature and with natural movements of population, the number of malaria carriers brought forward from year to year is therefore insufficient to maintain endemicity of malaria in England. Further, domestic, agricultural, and therapeutic factors, especially the last, have combined to limit the continuity of malaria in England. It is probable, therefore, that malaria never has been continuously endemic in England. The disease has depended for its indigenous recurrence on the importation of carriers and for its epidemic manifestation on the coincidence of high temperature of duration beyond the normal.

There are records of the occurrence of "ague" in Scotland, but it is improbable that malaria of indigenous origin has occurred in Scotland except in very limited volume in abnormally warm years.

In Ireland there is some evidence of the occurrence of ague, but, as in Scotland, the occurrence of indigenous malaria, except on the extreme south coast and in Dublin for a very limited period of the year, is also improbable. In normal years, during a portion of the months of July and August, malaria may occur in England south of latitude 54° 30′ N. In the presence of a sufficient number and suitable distribution of carriers, abnormally high and prolonged temperature is required to produce an epidemic; and to maintain endemicity, the abnormally high and prolonged temperature will have to be continued over many years.

This relation of temperature to malaria infection was manifested in England during the war. In the years 1917, 1918, and 1919 the main outbreaks occurred just about one month after the onset of a season of mean temperature reaching 60° F. with more or less daily continuity of that temperature. This suggests a period of about sixteen days for the development of *Plasmodium vivax* within *Anopheles maculipennis* at the temperature recorded; while about twelve days are allowed for the incubation period in man before onset of disease is manifested. In the year 1917 the mean temperature of 60·1° F. was reached by the month of June, and an outbreak of malaria occurred in July. In 1918 that temperature was not reached until the month of July, and malaria did not occur till August. In 1919 the necesssary mean was not reached till August, and the prediction of an outbreak of malaria about the end of August or beginning of September was fulfilled.

While this seasonal incidence in England was indicative of infection under natural conditions, when the outdoor temperature was sufficient for protozoal development within the mosquito, a certain number of cases occurred in the spring months when the temperature of the air reached a mean of from 45° to 51°F. This is a temperature at which, according to the evidence obtainable, malaria infection cannot be propagated in the mosquito. But the infection in these cases was certainly indigenous and occurred in early spring. At this season it is well established that the female imagines of *Anopheles maculipennis*, which have wintered in warm, sheltered stables, cowsheds, pigstyes, and similar places, where the survivors had fed during the winter on the blood of the housed animals, are depositing ova. In their chance flights for this purpose some mosquitoes stray into dwelling-houses and where conditions of shade, food, warmth, and freedom from disturbance are suitable, they will rest and feed on human blood. In such manner infection may be conveyed by a mosquito, and the period of rest afterwards may be sufficiently prolonged to allow development of sporozoits. Infection of other human beings living under the same roof thus takes place. At all events, in all the military cases of this kind that occurred in England there were established the facts of local movements of anophelines at a favourable time; the presence of active malaria carriers under the same roof as the victims at the time infection might be presumed to have taken place; and a continued indoor artificial temperature, during the period of protozoal development, sufficiently high to have ensured the development of sporozoits.

In the records from all malarial seats of war a definite spring increase of cases, followed by a period of absence of primary infection, was observed before the real summer and autumn incidence was manifested. Many explanations have been put forward to account for this, chiefly possible parasite vagaries, such as an annual cycle of development, but there has been nothing to support this theory other than the fact of the spring rise in cases of malaria. The habits of the anophelines in England give an obviously natural explanation of the occurrence there. In the evidence of similar occurrence in other parts of the world, the known habits of the local anophelines suffice to explain infection at a time of year when the outdoor temperature of the air is presumably insufficiently high or continuous for plasmodial sexual development to take place.

Further, the habits of *Anopheles maculipennis* in England explain also the lull in the appearance of primary cases between early spring and late summer. In the early spring months when bright sunny days bring the mosquitoes out to lay eggs, *A. maculipennis* is to be found sheltering in small numbers in warm sleeping rooms, but as fires cease in military huts and in bedrooms while the air temperature outdoors is still too low to bring the mosquitoes out, they remain in the warmer stables and other outhouses. Towards the end of March and during April, *A. maculipennis* has been found in small numbers in bedrooms, but has been very rarely found indoors between April and July. The period of wide summer distribution will vary with the temperature. When the temperature of the air rises to such a degree that it is immaterial to the mosquitoes whether they are in a stable or a bedroom, they are to be found in both. The food supply also determines that, having found a bedroom, they are more likely to stay there than in a stable where they found food when the cattle were indoors in winter months. These habits of *A. maculipennis* associated with the customs of the country, where it is the common vehicle of infection, account for the spring rise, the early summer absence, the late summer and the autumn incidence of malaria. Temperature conditions no doubt also determine the habits of the mosquito in the case of the different infecting mosquitoes in other countries.

In Macedonia, excepting a few cases, evidently primary, in April and May and one or two accepted as primary even in winter months, the incidence of malaria extends over the season from June to October or November. The third week in June in the years of the war was the date of rapid rise in the incidence of the infection with the *Plasmodium vivax*. *Anopheles maculipennis*, though dominated in the height of summer by *Anopheles palestinensis*, was in greatest evidence early in the year and was practically ubiquitous. Its winter habits and early spring movements were recorded as being identical with those observed in England. The facts of the seasonal development and the winter habits of the other anophelines of the Salonika area have not been sufficiently recorded.

The actual period over which infection with the *Plasmodium vivax* may occur in a normal season under natural conditions would appear to be from May to October, a period of at least six months. The continued prevalence of malaria in Eastern Europe is evidence that this extent of infective period is

ample for the maintenance of endemicity, a sufficient volume of malaria carriers being carried forward from season to season.

Whether temperature rules the relative seasonal occurrence of the infections of the different plasmodia of malaria there is not yet sufficient evidence to determine. The fact that a month later than the rise in *vivax* infections comes the rise in *falciparum* infections is certainly suggestive that higher temperature is required for the sexual cycle of the latter. Laboratory experiments in Salonika demonstrated that both parasites are viable in sixteen or seventeen days at a temperature of 72° or 73° F., the sporozoits of *falciparum* being perhaps rather later in maturing than those of *vivax*. No development of either took place at 55° F. Exposure to a freezing temperature for a brief period was found to retard and for a longer period to prevent development. Epidemiological observation suggests that with infection experiments at a temperature of 59° to 60° F. *vivax* would still have come on to sporozoit formation in about sixteen days, while *falciparum* would have been left either not to develop at all at that temperature or to take a month longer. A higher temperature over about the same period of time is required for the maturation of *falciparum*. Evidence of the seasonal incidence and temperature requirements of *Plasmodium malariae*, the parasite of quartan ague, is lacking, but the records of this form of infection amongst troops in Salonika are few. This infection was found, however, in relative frequency amongst the native populations in the immediate proximity of troops, and it is therefore surprising that so few cases were found amongst the troops. They were so few that it was not possible to refer their occurrence to any particular season. Similar localized distribution of the *Plasmodium malariae* has been observed elsewhere, and what little evidence there is of the temperature necessary for its sexual development suggests a higher or longer continued high temperature than that required by *vivax*.

The geographical limits of the three plasmodia of malaria are not established. Before the parasites of malaria were known, indigenous as well as imported infections by all three were regarded as occurring in latitudes where temperature conditions do not exist, or could not have existed, to bring about the indigenous occurrence of all three varieties. There was formerly a belief in the wider prevalence and higher incidence of quartan infections in temperate countries, but clinical grounds alone are insufficient to justify a diagnosis of malaria.

The geographical distribution of the different malaria plasmodia has, in fact, yet to be investigated.

The records of temperature, rainfall, and humidity for Salonika for the years of the war did not vary much from the normal mean. A mean of 60° F. and over was reached in the months of May to October. Rainfall averaged 16 or 17 in. for the year, of which rather over 5 in. fell in April to June and the same in October to November, while about 3 in. fell in each of the seasonal periods January to March and July to September. Humidity varied with fair constancy; the relative humidity rose to 80 per cent. in November to February, and fell to 60 per cent. in June to August.

In German East Africa or Tanganyika, which lies between the latitudes 5° to 10° S., there was evidence of a high incidence of malaria throughout the year. Cases were most numerous in March and April, but the records are insufficient either in extent or in detail to enable an estimate of the effect of seasonal influence on incidence, distribution, and parasite variety of malaria to be made.

In the plateau and mountainous districts of the interior rainfall is scanty. The dry season extends roughly from July to October. The eastern shores of Victoria Nyanza are dry, while there is a heavy rainfall on the western shores of the lake. The coastal regions have a moderate rainfall, and here the humidity is high all the year round, as it is for the most part around Lake Nyanza. In the interior, except in January, humidity is comparatively low.

The temperature along the coastal zone presents a mean of 77° to 82° F. for the whole year. The temperature in the interior varies considerably according to elevation, but is generally sufficient to maintain malaria in endemic form at a fairly high altitude. The seasons of drought and rain vary along the coastal regions and from the coast to the interior, as well as from east to west and in the interior from north to south. Malaria incidence is likely to be equally variable, but an accurate survey has still to be made.

In Mesopotamia, it is probable from the war records that malaria infection may occur in at least nine months of the year. July and August are the hottest, January and February the coolest months. The following temperature observations taken at different situations in the Euphrates and Tigris valleys in middle Mesopotamia show that except for December, January, and February a mean temperature of well over 60° F. probably occurs normally.

Temperature of the Air in the Shade on Euphrates and Tigris Lines of Communication.

Year.	Month.	Maximum. ° F.	Minimum. ° F.	Mean of Maxima and Minima. ° F.
1917	June	118·5	65·5	92·0
	July	122·2	71·8	97·0
	August	119·6	73·0	96·3
	September	116·2	60·0	88·1
	October	101·8	50·0	75·9
	November	90·6	46·0	68·3
	December	85·0	28·5	56·7
1918	January	75·7	32·0	53·8
	February	72·6	33·5	53·0
	March	82·0	42·0	62·0
	April	84·9	49·4	67·0
	May	107·2	54·5	80·0

As regards humidity, a difference of 20° to 30° between the wet and dry bulb was frequently recorded; occasionally the difference was only 7°. Records of rainfall are few. The rainfall in upper Mesopotamia near the mountains varied to a very great extent. In lower Mesopotamia it was scanty; July, August, and September were months without rain, while December and March were recorded as the months of greatest rainfall.

On the Tigris front the following records of rainfall were made:—

Year.	Month.	Period of Record.	Rainy Days.	Rainfall.
1916	January	16th to 31st	7	Steady rain from S.E. chiefly.
	February	1st to 29th	7	
	March	1st to 31st	9	Showers and thunderstorms.
	April	1st to 30th	6 (early in month).	
	December	6th to 30th	5	Steady rain.
1917	January	3rd to 31st	6	Steady, to short periods and storms.
	February	11th to 26th	6	Shower and thunder.

In the district around Nasiriya the first rain for the season in 1917 fell on 26th December, and only 2 in. of rain fell between that date and the following March.

The variations of temperature, rainfall, and humidity between the delta and the Persian and Transcaspian hill country were considerable.

In the Mesopotamian valleys and delta, alongside the rivers, canals, marshes, and irrigation tracts, it is probable that malaria will be endemic equally throughout the year except in the two or three winter months. The temperature otherwise is sufficiently high and rainfall is not necessary locally to maintain anopheline conditions. As habitations as a rule exist only where there is water, the occurrence of casual water resulting from rainfall is not likely to cause much increase in incidence of malaria. There is ground for believing that the mean temperature over certain months may be sufficiently high to check plasmodial sexual development. If there is no other reason than temperature to account for the fact that sexual development does not take place in the human body, a temperature of 98° F. will obviously prevent sporozoit development in the mosquito.

The records of the Egyptian Expeditionary Force so far as they relate to malaria are chiefly concerned with the occurrence of malaria amongst the troops in Palestine. The season of incidence was found to coincide with the temperature required for the transmission of infection. Primary infection was recorded in March in the Jordan valley, in April in the coastal plain, and in May in the hills around Jerusalem. A mean daily temperature of over 60° F. is recorded for March to December in the Jordan valley, for April to November in the plains, and for May to November in the hills. Rain falls generally from October to March and again in May. The other months are dry. The incidence of malaria, however, was little affected by the rainfall. This is accounted for by the fact that the natives live where irrigation is constantly carried on and where there are wells, so that mosquito breeding is continuous all the year round. In the deep wells both the imago and larva of *Anopheles bifurcatus* were observed throughout the winter, and primary cases of malaria are recorded as occurring in the winter months.

In Palestine, malaria, undoubtedly primary in origin, occurred amongst troops from December 1917 to March 1918, commencing about three weeks after the advance to the line of the Auja. Up to the last week of November 1917 a mean

temperature of over 60° was recorded, but from 1st December, 1917, to 13th April, 1918, no continuous mean of 60° F. was reached. It is obvious that abundance of anophelines would have developed sporozoits up to the last week of November, and would be capable for some time of causing infection, but the months December to March did not have a temperature sufficient to cause sporozoit development. The bulk of the outbreak occurred in January, chiefly in the first two weeks, which indicated that the infection took place in December. Cases arising later were considerably fewer and may have been delayed in onset. This corresponds with the generally acknowledged brevity of the period over which the mosquito may carry active sporozoits. There is no evidence that sporozoit development continued after November at the low temperature of the months December to March.

Infection with the *Plasmodium falciparum* seems to have taken place a month after the rise of the *vivax* infection, and the temperature observations suggest a similar cause.

In other regions of endemic malaria occupied by troops during the war, nothing of interest transpired in connection with the seasonal and meteorological aspects of malaria. Temperature was the main factor determining incidence, and latitude fixed the season of occurrence. Rainfall seemed in some situations to have little direct effect on incidence; in others it had a decided influence. This was due mainly to the nature of the country and the habits and pursuits of the people. In the former case continuous infection, increased by rise of temperature, was liable to occur when the inhabitants dwelt around permanent waters, especially in irrigation lands, while in the latter case infection occurred in populations living in upland and agricultural country which depended on rainfall and where casual water during the rainy season became infested by mosquitoes.

An interesting record of indigenous malaria came from North Russia. From the central laboratory at Archangel it was reported that 19 blood smears were examined for malaria in 1919, 1 in April, 2 in May, and 16 in June. Amongst these, 7 infections with *Plasmodium vivax* were detected, 1 in May, 5 in June, and 1 in July. Of the 5 in June, 3 were of Russians who had undoubtedly been infected in North Russia in May or early June. *Anopheles maculipennis* was found locally and typical breeding places were close by.

The air temperature in the shade at Archangel was as follows :

Month.	Maximum. ° F.	Minimum. ° F.	Mean of Maxima and Minima. ° F.
April	66	—11	27·5
May	78	13	45·5
June	83	26	54·5
July	85	34	59·5
August	82	33	57·5
September	69	23	46·0

These mean temperatures sufficiently indicate that indigenous malaria could occur only rarely. Infection in May and June must consequently have come from mosquitoes which had remained indoors at a high temperature for sufficient time to mature sporozoits. Occurrence of malaria infection in Archangel, therefore, corroborates the facts regarding its occurrence in England and in other temperate countries where malaria is normally absent.

During the years of the war malaria of indigenous origin was recorded as occurring in France, Flanders, Italy, Germany, Australia and America, in districts where it had long disappeared or where it had not previously been recorded. In all, however, the season of occurrence was compatible with infection of local anopheline mosquitoes, when temperature conditions were sufficiently high and prolonged to permit of the maturation of the sporozoits of *Plasmodium vivax*. Infection with *Plasmodium vivax* only was recorded, except in one case in France, where an infection with *Plasmodium falciparum* occurred after an intravenous injection of neosalvarsan, the explanation of which is by no means clear.

Entomological Factors.

The bionomics of the *Anophelinae* have a direct bearing on malaria prevention, as the only known vehicle for the transmission of malaria is the anopheline mosquito. Information is, however, incomplete regarding a variety of details concerning the life-history and distribution of species, but considerable

additions to knowledge on these points, of which the following is a summary, were made during the war in some of the theatres of operations.

In Macedonia, *Anopheles maculipennis* was reported to be practically ubiquitous, and to be essentially the anopheline of the plains, breeding especially in the weedy margins of the larger streams. This mosquito is said to be in greatest evidence in early summer, is probably a potent vector of malaria, and the female passes the winter mainly in buildings where cattle are housed. *Anopheles bifurcatus*, though not much in evidence throughout the year, was the first mosquito to be seen in spring; later it was rarely observed in dwellings and was found breeding usually in wells and in unshaded hill streams. The larvæ were found thoughout the year. *Anopheles palestinensis* (*superpictus*) was the predominant mosquito in later summer, especially on high ground, as it breeds in hill streams and is found everywhere; the female passes the winter in houses and outhouses occupied by cattle. *Anopheles sinensis* appeared early and was found mainly around the large lakes and marshy plains.

Observations on the controlled infection of *Anopheles maculipennis* and *Anopheles superpictus* indicated that, at a temperature of about 72° F., each may be infected with *Plasmodium vivax* and *Plasmodium falciparum*, while no infection with *Plasmodium malariae* was obtained in the few experiments made. Sporozoits were found in the salivary glands after thirteen to seventeen days. Infection with *Plasmodium falciparum* was more frequent than with *Plasmodium vivax*, where the source of infection had been a patient taking quinine. *Plasmodium falciparum* developed more rapidly in *Anopheles superpictus* than in *Anopheles maculipennis*.

At a temperature of 55° F. development of parasites did not take place in either mosquito , and the temperature of the ice chest for twelve hours retarded but did not prevent development on subsequent incubation at 72° F. Exposure to low temperature for some days stopped development. In mosquitoes kept at 55° F. for a fortnight and afterwards at 72° F., development proceeded only if the initial temperature had been above 60° F. at the time of blood-sucking. Oöcysts have been found, but no sporozoits, in the months from November to April.

In general, the critical range of temperature of sexual plasmodial development was not ascertained.

The records from Palestine showed the presence of the following varieties of mosquitoes and their habitats.

Species.	Remarks.
Anopheles palestinensis	Commonly found: the larvæ are present in hill streams and valley swamps.
Anopheles bifurcatus	Adults and larvæ are found the whole year round in deep wells in hill country and on low ground: very common.
Anopheles maculipennis	In *wadis*, backwaters and marshes: adults in swarms in early June: common.
Anopheles mauritianus	In weedy margins of valley streams.
Anopheles pharoensis	Reported from the coastal area.
Anopheles algeriensis	Not common: found in Abu Zeitun marsh in May and June.
Anopheles sinensis	Common in June: larvæ in marshes and backwaters.
Anopheles turkhudi	Common in the *wadis* of the Jordan valley.
Anopheles fragilis	Recorded.
Anopheles pseudopictus ..	Recorded.

A brief summary of the anophelines recorded in other theatres of war is as follows:—

Country.	Species.	Remarks.
Mesopotamia ..	*Anopheles nursei* *Anopheles pulcherrima* *Anopheles palestinensis*	Recorded.
Egypt	*Anopheles pharoensis* ..	"The common Egyptian malaria transmitter."
East Africa ..	*Anopheles costalis* *Anopheles funestus* *Anopheles mauritianus*	Around Dar-es-Salaam, Kilwa Kivinje, and in coastal area generally.
France, Italy and England.	*Anopheles maculipennis*	Common: larvæ in weed-grown ditches, swamps, streams, etc. The female winters in sheltered stables, etc.
	Anopheles bifurcatus ..	Not frequently seen in dwellings except in spring: larvæ in ponds and ditches the year round.
	Anopheles plumbeus ...	A treehole breeder: capable of carrying malaria.
Russia (Archangel)..	*Anopheles maculipennis*	Larvæ in weed-grown marshes, etc.

Parasitological Factors.

The three recognized malaria parasites were met with on all army fronts where malaria was endemic. Out of the many thousands of blood examinations made for malaria investigation alone no others than these were recorded or suggested. Nor were the accepted cycles of development questioned. The parasite of the benign tertian malaria, *Plasmodium vivax*, was the cause of the disease in the vast majority of the troops affected. Infection by the *Plasmodium falciparum*, the parasite of malignant malaria, was in considerable evidence either as a simple infection by itself or in a combined infection along with *Plasmodium vivax*, or very rarely with *Plasmodium malariae*, the parasite of quartan infection. The latter was the least frequent form of infection.

In spite, however, of the large numbers of cases of malaria, the conditions under which observations were carried out prevent any general conclusions being made regarding the relative incidence of the varieties of malaria parasitic infections.

In season of incidence the infection by *Plasmodium vivax*, as already noted, precedes that by *Plasmodium falciparum* by a month or more in countries where winter conditions prevent infection all the year round, and the maximum incidence of *falciparum* infection may be two months later than the *vivax* maximum. Records of infection by *Plasmodium malariae* are too few to determine its relationship to season. Its occurrence in localized areas, as had been observed previous to the war, was again noted.

While *vivax* and *falciparum* infections are found wide spread wherever malaria is met with, the *P. malariae* infection is not continuously distributed. In any given malarious area the two former parasites will usually be found over the whole area, while the quartan parasite, if found at all, will almost certainly be found in limited districts within the malarious area.

The virulence of the different parasites has been variously adjudged, but the general opinion appeared to be that the *Plasmodium falciparum* infection was liable to produce the most acute symptoms, the most profound morbific and fatal results, to be most amenable to treatment by quinine, and to be followed by the most speedy convalescence if promptly treated; while the *Plasmodium vivax* infection, causing benign tertian malaria, when uncomplicated, was not a cause as a rule of serious acute symptoms and rarely produced profound and fatal results, but unless treated at the very commencement,

was only slowly eliminated by quinine and was apt in its long continuance to produce chronic debility, anæmia, and cachexia.

The *Plasmodium malariae* was usually credited with originating an insidious infection often without urgent febrile reaction, but capable of causing and maintaining a state of chronic debility and profound anæmia.

The identification of the infecting parasite was therefore essential for accurate diagnosis, and the later war records give evidence of a great advance in this respect.

The preparation of blood smears for diagnostic purposes was simple and easy, and for accuracy and speed in diagnosis the thick film method was best. Consequently there was no difficulty with any of the conventional staining methods in ascertaining the presence of a parasite. But while the accurate differentiation of type was generally easy, there were some cases where it was practically impossible. The schizonts of *vivax*, the gametocytes of *falciparum*, and the small mass pigmented schizonts and gametocytes of *P. malariae* are specifically characteristic, but any attempt to decide on the type of parasite from equivocal young forms was useless. In doubtful cases, however, further blood examination would always determine the species.

In any case of acute fever due to malaria the parasite will be found if sought with care and skill. Even for several days while under quinine treatment the parasites of all three types could be found in the majority of cases. In "quinine-resisting" cases of *vivax* infection typical schizonts and other forms might occasionally be found in spite of continued quinine-taking. The gametocytes of *falciparum* could be found even for weeks during a course of quinization. Immediately after an attack of blackwater fever parasites were rarely found. In some cases parasites might be found in very small numbers.

No diagnosis of malaria was reliable without the demonstration of the parasite in a blood smear, but blood examination of every case was unnecessary by the practitioner in notoriously malarial areas. In these, clinical symptoms and reaction to specific treatment were sufficient for diagnosis. But a febrile condition continuing in spite of quinine treatment demanded blood examination.

At Sandwich, Kent, where anopheline conditions exist, a laboratory was established and equipped as a centre for entomological investigations and a school of practical anti-malaria training; at Blackpool an army school of hygiene,

ably staffed and well equipped, included entomology and anti-malaria operations in its curriculum, and at Leeds another school of hygiene was a centre of general instruction.

Morbid Significance.

The mass debility resulting from malaria, the loss of labour in agriculture and in other industries, and the loss of strength in armies in peace as well as in war, far exceeds the losses from any other disease.

In armies the debility resulting from malaria caused an immense loss of strength. Exposure, exertion, and fatigue magnified its effects, and the sufferers nearly all came under medical treatment and had to be admitted to hospital. In civilian communities infected individuals could treat themselves and could carry on their occupations. But in the army the acute stages of malaria could rarely pass without medical observation, and the medical officer's sense of responsibility could not as a rule allow him to risk men going on duty with acute malaria, except in face of the most urgent military requirements. Consequently the sickness in armies exposed to malaria infection was high and, in addition, the men who remained on duty gradually deteriorated in fitness for field service. They were chiefly composed of men discharged from hospital and of men who had been able to remain on duty in spite of malaria infection.

On the different army fronts in Eastern Europe, Palestine, Mesopotamia, and East Africa, the loss of strength and general deterioration of troops in the field from this cause were very great.

The extensive infection of the Macedonian Expeditionary Force was similar to that of the British armies in practically the same area during the Crimean War. In August 1855, from being in extraordinarily fit condition in the previous months, the armies in the Balkan peninsula were suddenly prostrated by disease. Apart from the hospital sick, it was universally admitted that no man in the ranks, though not on the sick list, was capable of active field service. The presence of endemic malaria throughout the Balkan provinces was well known, but the nature of the disease and the simplicity of its prevention had not at that time been enunciated.

In the years 1916–19 there was a repetition of this experience, although both the nature of the country and its inherent malarial dangers were pointed out from the very first by the medical authorities. Early and continued occupation by

troops of notoriously malaria-infested situations, however, took place. In spite of the recognition of malarial conditions by the medical authorities troops as a whole were slow to recognize the danger of malaria.

The following table gives the hospital admissions for malaria in the Macedonian Expeditionary Force. Invaliding to the United Kingdom commenced in 1916.

TABLE I.

Malaria Hospital Admissions in the Macedonian Expeditionary Force.

Month.	Years.			
	1916.	1917.	1918.	1919.
January	—	677	2,513	1,083
February	—	1,114	2,487	502
March	—	2,553	5,107	631
April	—	2,233	5,634	665
May	—	2,759	5,921	470
June	—	3,139	7,655	640
July	—	6,228	5,714	768
August	—	9,242	5,675	943
September	7,016	16,488	5,004	837
October	6,872	15,921	5,555	582
November	2,788	7,200	5,670	306
December	1,386	4,859	1,852	53

Notwithstanding the evacuation of the infected, the disease spread in the armies to such extent that whole battalions were considered practically unfit for field service. Orders were issued prohibiting the return of malaria cases to a malarious seat of war, and although this may have temporarily kept the forces free from malaria during the winter season, the rate of admissions for malaria in the infective season seems to have been maintained.

In the succeeding years of Macedonian occupation, however, while the incidence of malaria varied according to the seasons, the fluctuation in the total strength of the armies and the changes of locality of their distribution, there is evidence to show that primary infection was considerably reduced, especially in 1918.

In January 1918 the evacuation of debilitated troops was commenced on an extensive scale, and during the ensuing twelve months a great part of the armies in Eastern Europe was transported to Britain and France for treatment. The debility

of those arriving in England cannot be said to have been, except in a few cases, serious. In the mass, however, the result of having thousands of men infected with malaria was a serious problem. In civilian life a great proportion of those invalided from field service would have struggled to carry on their occupations, but the requirements of military service aggravated the physical debility and malaria was consequently much more disastrous in armies than in civil life.

While there is evidence of a wide dissemination of malaria infection throughout Mesopotamia, there was no wholesale disabling of soldiers by the disease to the same extent as in Macedonia. Table II shows the incidence of malaria on the Mesopotamian troops. On the lines of communication it was possible, to some extent, to choose sites for camps which were removed from intense malarial conditions. Where camping grounds were in immediate touch with mosquito-breeding, measures of protection, screening, and mosquito destruction were employed.

TABLE II.

Malaria Hospital Admissions. Mesopotamia.

Month.	Years.		
	1917.	1918.	1919.
January	—	515	499
February	256	249	276
March	569	319	216
April	544	365	129
May	514	489	311
June	714	889	852
July	652	1,069	1,175
August	593	920	655
September	766	807	336
October	772	1,309	274
November	752	2,457	359
December	591	943	179

In the following table of malaria incidence in the Egyptian Expeditionary Force the cases chiefly occurred in Palestine. The loss of strength was undoubtedly high, but the extent of primary infection is not readily ascertained, relapse having been frequent amongst troops originally infected in Macedonia as well as at an earlier date in Palestine.

TABLE III.

Malaria Hospital Admissions. Egyptian Expeditionary Force.

Month.	Years.			
	1916.	1917.	1918.	1919.
January	—	240	784	1,322
February	—	183	948	946
March	—	160	1,648	992
April	—	84	1,384	791
May	—	122	1,149	738
June	—	248	2,256	621
July	—	507	2,889	*447*
August	—	419	3,776	*348*
September	—	2,191	2,531	*324*
October	352	2,187	4,569	*347*
November	201	1,194	6,273	*386*
December	147	945	2,034	*146*

Figures in italics refer to white troops only. Others include Indian troops.

There is evidence of reduction in primary infection as a result of preventive measures, although the extent of these was restricted by the military operations.

Amongst the troops in East Africa malaria accounted for 60 per cent. of all admissions to hospital in 1917, and amongst followers and carriers for 29 per cent. of all admissions.

In other seats of war, malaria, which had been acquired chiefly in the endemic areas of Macedonia, Mesopotamia, Palestine, and East Africa, was a source of frequent and considerable loss of strength. In Italy and France a certain amount of malaria occurred. In England, in spite of meteorological conditions unfavourable to the spread of malaria, several cases occurred up to 1919, chiefly in 1917 before the factors determining indigenous malaria in England were fully appreciated, and in small number after preventive measures were instituted in the areas which were considered dangerous.

In England the medical services were chiefly concerned in dealing with carriers of malaria infection. Of these the total numbers evacuated to England in 1918 from Salonika were some 30,000, and this is only a proportion of the total evacuated from all theatres of war. The minimum period of detention for treatment at concentration centres and in units in the United Kingdom was sixty days; and when to this is added the inevitable time spent in passing through depôt, unit, and in many cases hospitals, the loss of strength to the armies may be realized.

Preventive Measures.

Active measures of immediate malaria prevention were elaborated in greater or less perfection on the different army fronts.

The Macedonian Expeditionary Force, both in the number of troops and in the length of the period of exposure to malaria, had the greatest experience of preventive measures, and a description of these derived from the reports of the force is generally applicable to the Egyptian, Mesopotamian, and the East African Expeditionary Forces, and to some extent to the armies in Italy, France, and England.

These preventive measures may be classified as follows:—

1. *Drug prophylaxis and treatment.*
2. *Culicifuges* or mosquito deterrents.
3. *Personal protection*
    - (*a*) Siting of camps.
    - (*b*) Evacuation of areas.
    - (*c*) Screening of dwellings.
    - (*d*) Clothing:
        - (i) Head nets.
        - (ii) Gloves.
        - (iii) Flapped shorts.
        - (iv) Sleeping nets.
4. *Mosquito destruction.*
    - (*a*) Destruction of imagines.
    - (*b*) Destruction of ova, larvæ, pupæ:
        - (i) Disinfectants.
        - (ii) Oiling.
        - (iii) Conversion.
    - (*c*) Removal of breeding places.

Prophylaxis and Treatment.—The term "prophylaxis" in respect of malaria has long been used to designate the attempt to prevent the infection by means of a drug. The drug universally employed for the purpose has been quinine; and there have been rare trials of the prophylactic power of arsenic and other drugs.

The value of quinine as a prophylactic had been the subject of much debate previous to the war.

During the war, on the different army fronts where malaria conditions existed, quinine as a prophylactic was extensively used, but there appears to have been no consensus of opinion as to its value. The evidence generally, however, was against the practicability of its use as a prophylactic.

Opinions were called for from medical officers, who were controlling the quinine prophylaxis, with the following result :—

Reports received :	
No opinion expressed	14
Opinion uncertain	4
" Of great value "	2
" Of definite value "	2
" Of some value "	10
" Of very little value "	18
" Of no value "	72
" Of no value and objectionable "	7
Number of reports received	129

These opinions are perhaps of little or no value as a scientific estimate of the efficacy of quinine in preventing malaria infection ; but the evidence of all the armies points to difficulty in obtaining malaria prophylaxis by the administration of quinine.

Treatment has its place in the prevention of malaria in so far as the earlier a case is cured the shorter is the period of carrier infectivity. Some degree of prevention must have been derived by treating to a cure not only the soldiers but also the civil population in their vicinity ; but notwithstanding this a large number of gametocyte carriers, untreated or under treatment, was continuously in contact with troops and was thus a definite source of infection. It was inevitable amongst both soldiers and civilian populations that early malaria infection very frequently remained untreated. In fact, for many reasons, early treatment of malaria in armies has not been of any great value as a practical measure of prevention. With regard to the experience of treatment of great numbers of cases in hospitals overseas and in the United Kingdom, much has been written and published, from which the following appear to be the general conclusions regarding the cure of carriers by means of treatment.

In spite of much and varied experimentation no drug has been found to have any specific action on malaria except quinine.

No method of administration, other than the long-recognized oral exhibition of the drug, has been proved to be of superior value in the routine treatment of malaria.

In certain cases of exceptional severity, naturally rare but which for obvious reasons were abnormally numerous amongst soldiers, the recognized methods of intravenous, intramuscular, and subcutaneous injection of quinine are justified and at times necessary.

The early or immediate and prompt treatment of malaria by quinine in doses of 10 grains three times a day quickly cures the disease in a large proportion of the cases.

Successful treatment of malaria, which had been for a long time untreated, of cases insufficiently or irregularly dosed, and of relapsing cases depends on prolonged regular quinization.

No rapid sterilization of the system in relapsing cases has been achieved by any method or any drug.

From these facts it is evident that, in the prevention of malaria, the co-operation of the therapeutist, in the early and effective treatment of cases, is a valuable addition to other measures; and further, the experience of practical warfare demonstrates the very limited help which it is possible to expect from early cure of malaria amongst soldiers under active fighting conditions.

Culicifuges or Mosquito Deterrents.—The application to the skin of substances believed to repel mosquitoes has been a measure in use from time immemorial. Popular confidence has been placed mainly in essential oils. During the war fairly extensive laboratory investigations were conducted with the view of determining the repellent power of different ointments, pomades, pastes, waxes, powders, oils, liquids applied to the skin or sprayed.

The results were unsatisfactory. Substances credited with virtue in one area were discredited in others. Opinions were contradictory as to whether a brief relative efficiency of any substance depended on odour, consistence, or toxicity. It was suggested that an estimate of the value of a deterrent by the olfactory sense of man might have no analogy in the mosquito, and that the whole question of mosquito attraction and mosquito repulsion was most properly approached from the standpoint of mosquito physiology and psychology.

The general conclusion is that it has not been demonstrated that "culicifuge" preparations have any value as an anti-malaria measure of such certainty as to warrant the expense of their being supplied to troops.

Personal Protection.—Siting of camps obviously is a vital factor in the defence against malaria, but one which in actual warfare it is difficult to control. At the same time it should have been possible to take far greater advantage of topographical conditions than appears to have been the case in the different theatres of war. Medical and sanitary authorities could not avoid having grave doubts as to the strategic necessity for many of the encampments and movements of

troops, although they were personally unable to control these. So far as malaria prevention went, the ideal site was almost always the same as would have been selected on general hygienic grounds and also frequently on strategic grounds. Elevation, absence of stagnant water, porosity of soil, free drainage, windward relation to marshy ground, were some main points to be considered; but with the exception of the siting of hospitals, evacuation, and segregation camps, little attempt appears to have been made to encamp troops in areas removed from malaria infection.

Evacuation of areas was carried out in some cases. In others removal of the infected troops and civilians formed part of the measures of segregation; and extensive evacuation was recommended of specially malarious areas. But while evacuation of highly malarious areas is justifiable, especially when other means of combating malaria are impossible, wholesale evacuation is unnecessary when other measures are applicable.

Screening of buildings was widely adopted. All hutted hospitals were provided with wire gauze over windows, louvres, and doorways, although double doors with porch were not in general use. Huts in the most malarious parts of the base and lines of communication at Salonika were similarly screened. Numerous mosquito-proof shelters were provided, and dugouts were protected.

There was ample evidence of great reduction in the numbers of mosquitoes found within buildings, though screening was not universally used and was not ideally adapted.

Clothing as a protection was variously conceived. Head-nets were in use, constructed of muslin draped on metal or cane rings of wide circumference, so as to keep the muslin well away from the head and of sufficient length to allow of their being tucked in at neck and shoulders, where the muslin should "bag" and float free. These head-nets could be used as a miniature mosquito net during sleep.

Gloves or gauntlets were of finely woven cotton material; large, roomy, long, and capable of being fastened by tape or button to prevent slipping down. They were said to have a certain protective value.

Flapped shorts were made so that the flap might be turned down over the knees under the puttees during the hours of exposure to mosquitoes. The flap should be long to prevent it working out of the puttees, and should make a baggy cover over the knees.

Fig. 1.—A general view of the special protective clothing in use. A head net is worn over a shrapnel helmet, and the special pattern shorts are turned down under the upper turn of the puttees. The gauntlet gloves are seen on the hands and forearms.

Sleeping nets were much used. In theory the use of the mosquito net should go far to eliminate malaria. The practical

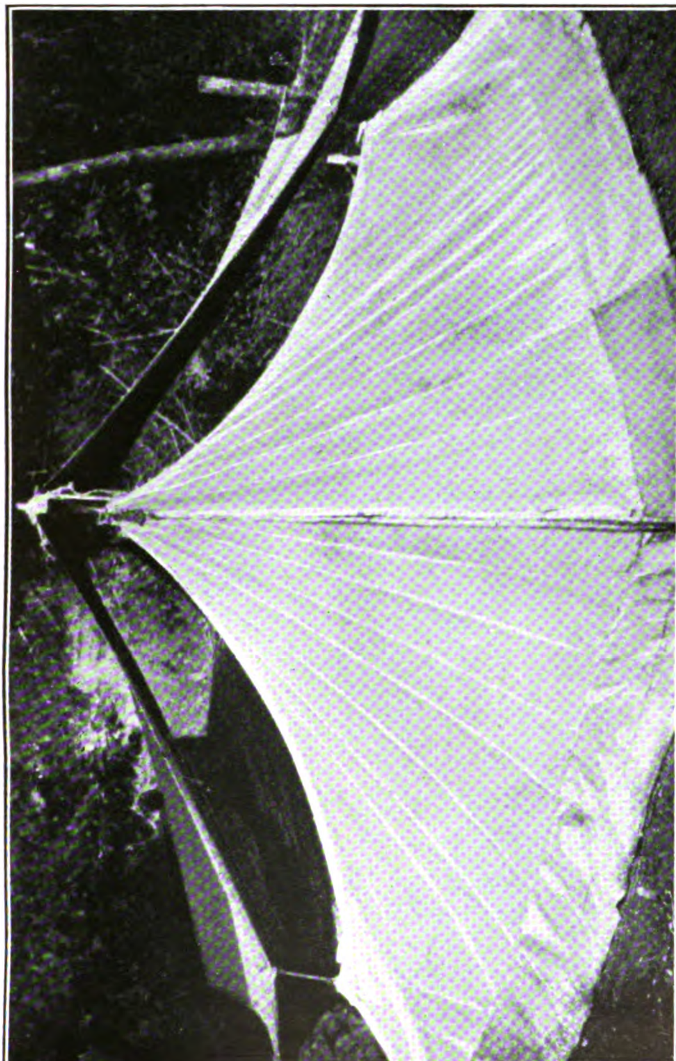


Fig. 2.—Bivouac pattern mosquito net pitched so as to show the air space between the net and the bivouac sheet.

difficulties in the way of ensuring their universal use, in maintaining them in perfect repair, and the strategic necessities

which prevented their careful handling and disposition, detracted from their value in the case of armies in the field ;

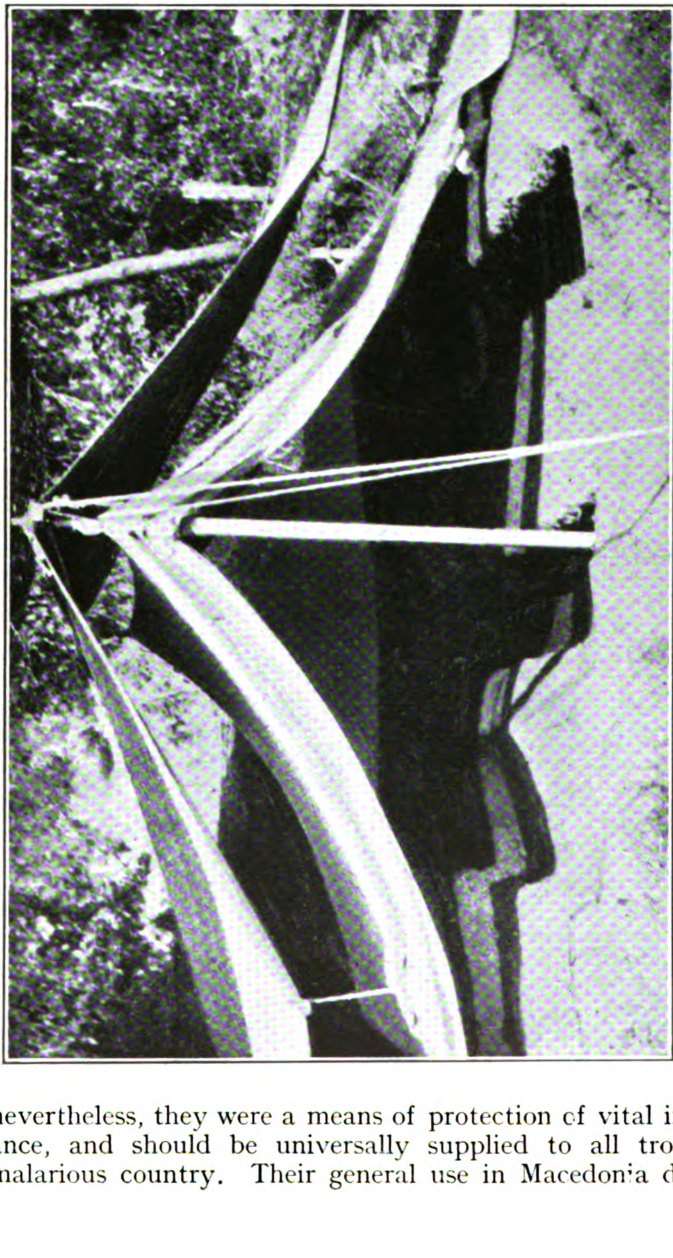


Fig. 3.—The same net as in Fig. 2, open to show interior dugout. The ledges forming beds are dug down to a depth of 9 in. and the central trench for feet is dug down to a depth of 18 in.

nevertheless, they were a means of protection of vital importance, and should be universally supplied to all troops in malarious country. Their general use in Macedonia did not

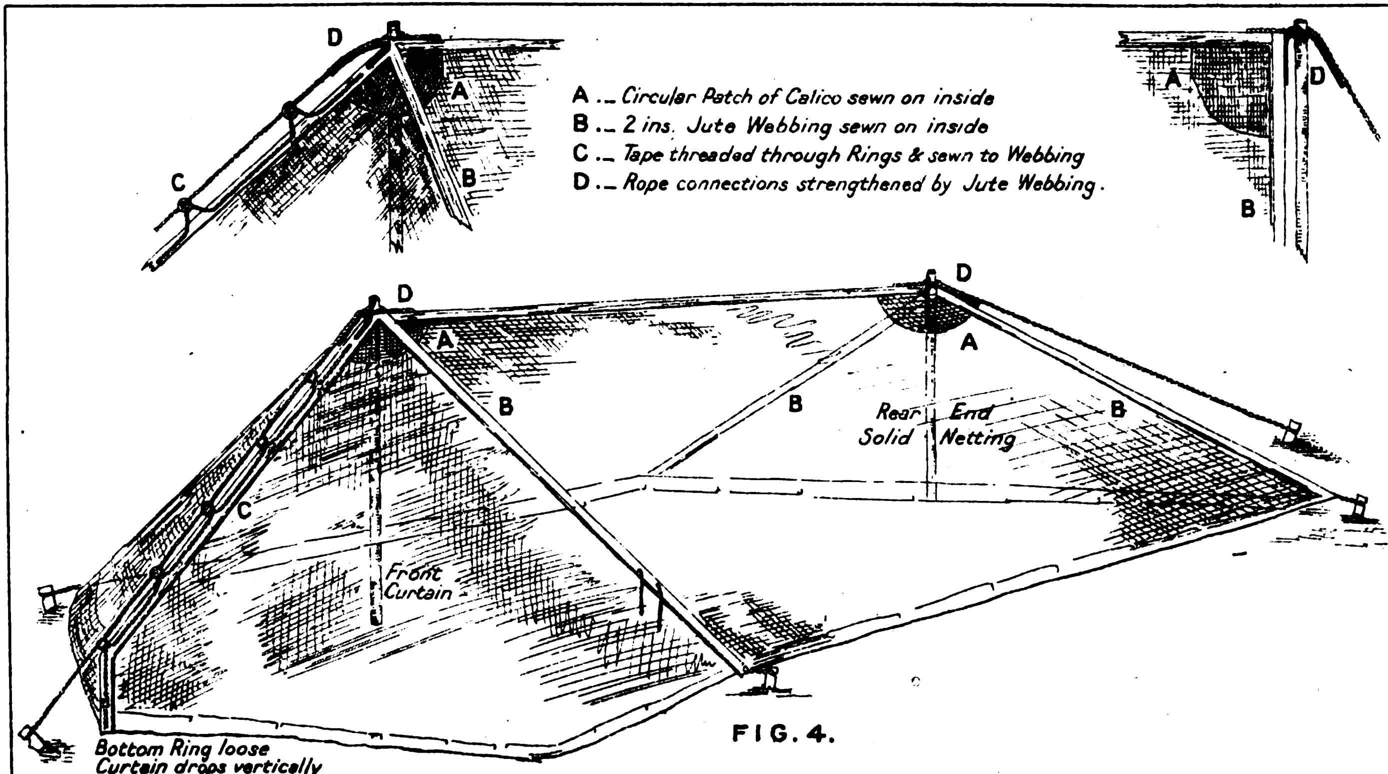


FIG. 4.

ALTERATIONS TO BIVOUAC NET.

Malby & Sons. Lith.

take place until after wide exposure to infection, but all the troops were supplied with bivouac nets by July 1917.

All patients in hospitals and casualty clearing stations were supplied with bell nets, and 150 were distributed to each field ambulance. In addition, many bell nets and nets for circular tents were issued.

The mosquito nets were made in muslin material of sixteen meshes to the inch, or of twenty-two meshes to the inch, the latter for prevention of sandfly infection. The patterns in use were the bivouac net, the net for circular tent, and the hospital pattern.

The bivouac net consisted of a mosquito-gauze lining to the bivouac shelter when put up in the normal way. The net had no openings; but one end was extended outwards and supported from the guy rope by metal rings threaded on tape sewn to jute webbing. This extension could be raised to admit of entrance or exit and automatically closed by its own weight, there being pockets at its lower border containing sand or stones. Tapes held the net to the edge of the bivouac sheet. Jute webbing was used to strengthen rope connections, and canvas, jute webbing, or calico was sewn on at supporting corners and edges. Two men could lie lengthwise in the bivouac without the net touching them.

Nets for circular tents made a complete inner lining in the tent. No opening was provided, enough "slack" being left opposite the door of the tent to allow entry by lifting. Patterns with laced or buttoned opening were unsatisfactory.

The hospital bell net was the conventional pattern of net. It was issued to hospitals, casualty clearing stations, huts, houses, marquees, regimental aid posts, and was adapted also for bivouac tents and dugouts. Two or three men could sleep under one net. The hospital bell net was the most generally serviceable and adaptable to varying conditions of situation and usage.

Mosquito destruction, when energetically and wisely pursued, constantly gave immediate and obvious results. While strategic considerations hindered this method of prevention there were many occasions in which local measures were successful, but the evidence of which did not appear in the general incidence of malaria. Of these the most notable instances were a great reduction in primary malaria in Salonika in 1918, notwithstanding the high carrier rate within the army; a similar reduction in East Africa in the later years of the campaign; and a comparative freedom from primary infection

amongst troops in Palestine during a period of rest in malarious regions where active preventive operations were in force.

In Salonika the reduction of infection was progressive, the records showing that in 1916–17 of 63,310 hospital admissions for malaria, some 60 per cent. were recurrent, while in 1917–18 of 67,059, the recurrent cases were 91 per cent. In East Africa in 1917 the admissions for malaria were 70 per cent. of the whole, a figure which was greatly reduced in 1918 and 1919. In Palestine also the records of infection in different corps and at different times show a definite limitation during stationary periods of warfare. The evidence of this, however, is not clear from the figures of total admissions, as any advance of the troops was invariably followed by primary infections, sometimes of wide extent. In more defined situations, evidence of malaria reduction by extensive mosquito destruction was again established, notably at Taranto, and in the malarious areas of England, at Sheppey and Sandwich. Taranto had been suspected with good reason of being the seat of origin of much primary infection, especially of troops in transit. Preventive measures, however, the main factor of which was mosquito destruction, practically obliterated all record of primary infection amongst local units and transit troops. At Sandwich, in Kent, in 1917 there were sixty-nine recorded cases of primary malaria infection amongst a large body of troops engaged chiefly on engineering works, and there were probably many more. In 1918, after the prosecution of mosquito limitation, there occurred six primary cases.

In all situations the reduction of mosquitoes was marked, and in some localities there are records of practical elimination.

The general principles of mosquito limitation have been common to all regions ; actual operations have varied according to situation, climate, available personnel, and military operations, defensive and offensive. The influences of situation and climate have already been considered to some extent. Anti-malarial work on the different army fronts was often hazardous, the anti-malarial parties frequently coming under shell fire, and results were disappointing when the troops had to advance into territory where preventive measures could not have been carried out.

In Salonika the anti-malaria work in corps areas was conducted by divisional and corps sanitary sections. The officer in charge of the sanitary section was the anti-malaria officer ; squads were distributed to initiate and supervise the work. In units the work was carried out by labour parties of 25, 50,

100, or up to 25 per cent. of the units as required; and also parties of 50 from field ambulances were engaged on anti-malaria work when available. Surveys and progress reports were submitted with sketch maps of areas. An officer with experience of tropical diseases was appointed to each brigade as anti-malaria officer to supervise measures and give advice.

The establishment and equipment of an anti-malaria working squad in Salonika were as follows:

Anti-malaria Working Squad.

Establishment and Scale of Equipment.

(1) *Establishment.*

Detail.	Cpls. or L.-Cpls.	Privates.	Total.
Labour	2	21	23
R.A.M.C.	1	2	3
Total	3	23	26

One cook was included in the above. The labour personnel was British, Maltese, or Macedonian.

(2) *Equipment.*

Article.	Number.
Axes, felling, C.H.	2
„ hammer headed	4
„ pick, heads	10
„ „ helves	10
Brooms, bass	6
Cans, watering*	4
Crowbars	2
Hammers, sledge	1
Hooks, bill	4
Knives, long hedging*	4
Lamps, hurricane	3
Rakes, garden*	6
Saws, hand	1
Scythe	1
Shovels, G.S.	12
Sickles	2
Sprayers, "New Rapid"	2
Stones, rub, scythe	1
Points, steel or jumpers	2
Wheelbarrows	2
Boots, gum, long	prs. 2
Gloves, hedging	prs. 6

Articles marked * were improvised locally. Camp equipment was issued for British and Maltese personnel, and also for Macedonians.

Every anti-malaria squad was furnished with apparatus for making collections and for identifying mosquitoes and larvæ.

In Palestine, anti-malaria squads were formed in every unit. These were additional to the sanitary squads. They were of the following strength :—

Each infantry brigade	1 N.C.O.,	6 men.
,, brigade R.F.A.	1 ,,	5 ,,
,, field company	1 ,,	2 ,,
,, train company	1 ,,	3 ,,
,, machine gun company	1 ,,	2 ,,
,, field ambulance	1 ,,	6 ,,

Squads were instructed by the medical officers of their units, assisted when necessary by the divisional sanitary sections. The duties of malaria squads were to discover the breeding places of mosquitoes within a radius of 600 yards of the unit's camp or billeting area ; to canalize properly all streams ; to clear all streams and pools of weed and undergrowth ; to drain all pools where possible ; to get rid of promiscuous collections of water in old tins and pots ; to oil water that could not be drained ; and to cover with sacking or other material all openings into wells and cisterns.

The squads were under the control of the regimental medical officers, and a brigade malaria officer was appointed from one of the field ambulances to supervise and control the work of each brigade area. The area which did not come under the surveillance of the regimental medical officers was dealt with by the O.C. Sanitary Section and his personnel. These officers in turn were responsible to the D.A.D.M.S. (Sanitation) of the division.

Maps, reports, and surveys were prepared in connection with the work. This scheme, generally speaking, was adopted by all corps, but for major operations, such as the drainage of large marshes or the clearing of the banks of the River Auja, the assistance of the Royal Engineers and companies of Pioneers or of Egyptian Labour Corps was obtained.

As a result of extensive draining of marshes and canalization of rivers, larvæ and adult mosquitoes were reduced to a minimum by August, when under natural conditions it might have been expected that their numbers would have been rising to a maximum. The incidence of malaria amongst the troops fell coincidently with the disappearance of anophelines. The total loss of men to the army corps from malaria was only about 10 per cent. of the strength during the twenty-one weeks under consideration, with the result that the troops were able during the autumn to engage in a most arduous campaign.

On the Salonika front drainage, levelling and canalization, diversion of streams, removal of vegetation, training and clearing of channels, and continued maintenance were carried on extensively in many localities. In 1918, 479,991 yards of new trenches were cut ; 1,670,506 yards of old trenches refreshed ; 9,690 yards of pools filled in or drained ; 1,157,192 yards of water surface oiled ; and 363,315 yards of brushwood cut. In

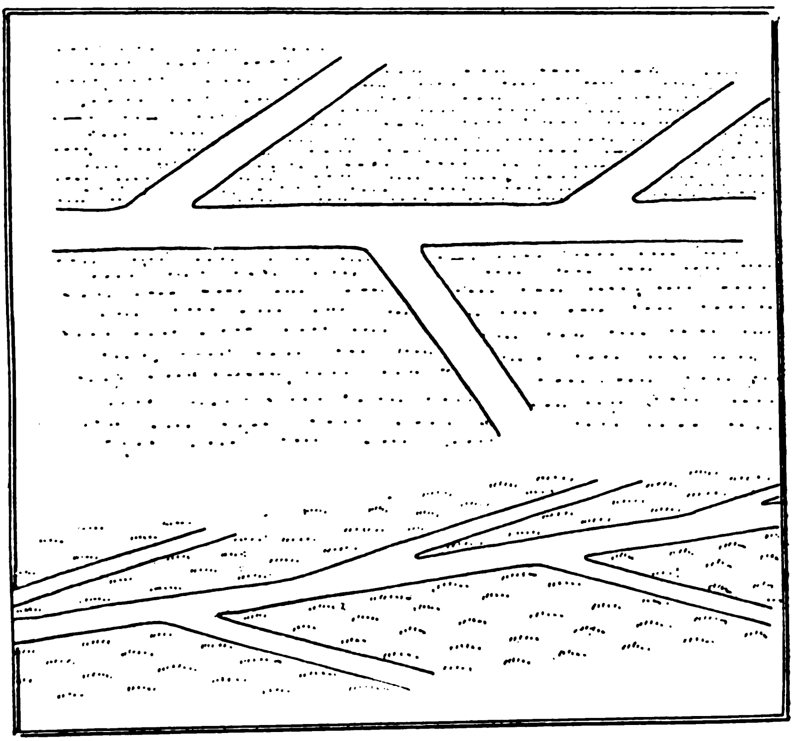


Fig. 5.—Diagram to illustrate "herring-bone" drainage of a marshy area. The main channel is cut to follow the fall of the ground with branch channels draining into it.

one divisional area 47,306 yards of channeling (6,114 yards of new work) were finished, and 87,106 yards of ground were cleared in one month.

The actual details of anti-mosquito operations are innumerable and varied, differing in every situation, and according to the knowledge, ingenuity, and common-sense of the director. The experience of the war cannot be said to have evolved new

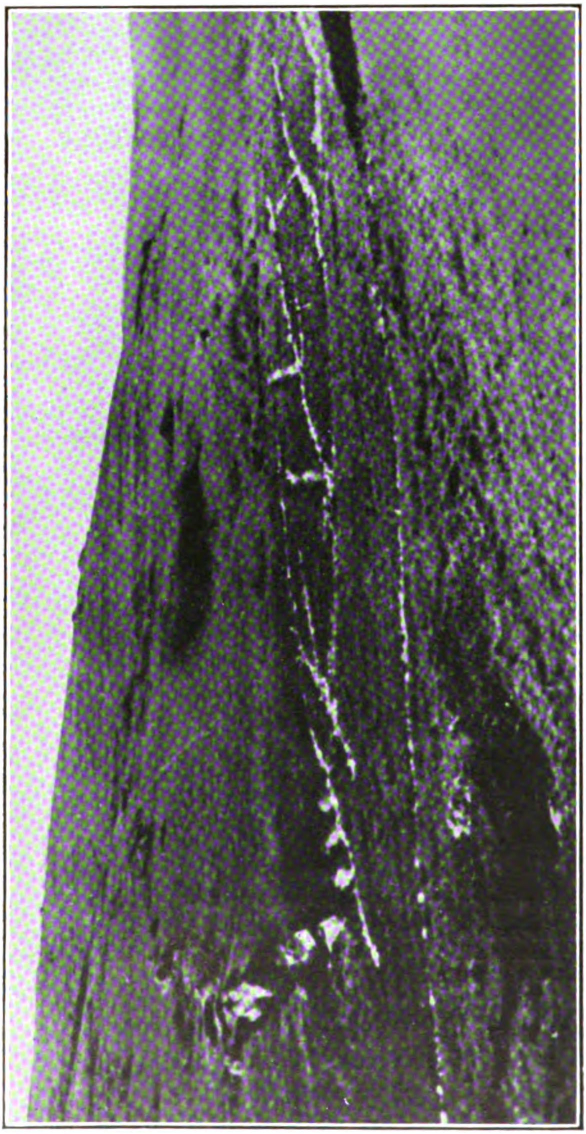


Fig. 6.—"Herring bone" drainage of a bog formed by the outcrop of a small hill stream. Owing to the sponginess of the ground the drains were lined and covered with stones. At the time the photograph was taken, the work had stood eighteen months without repair.

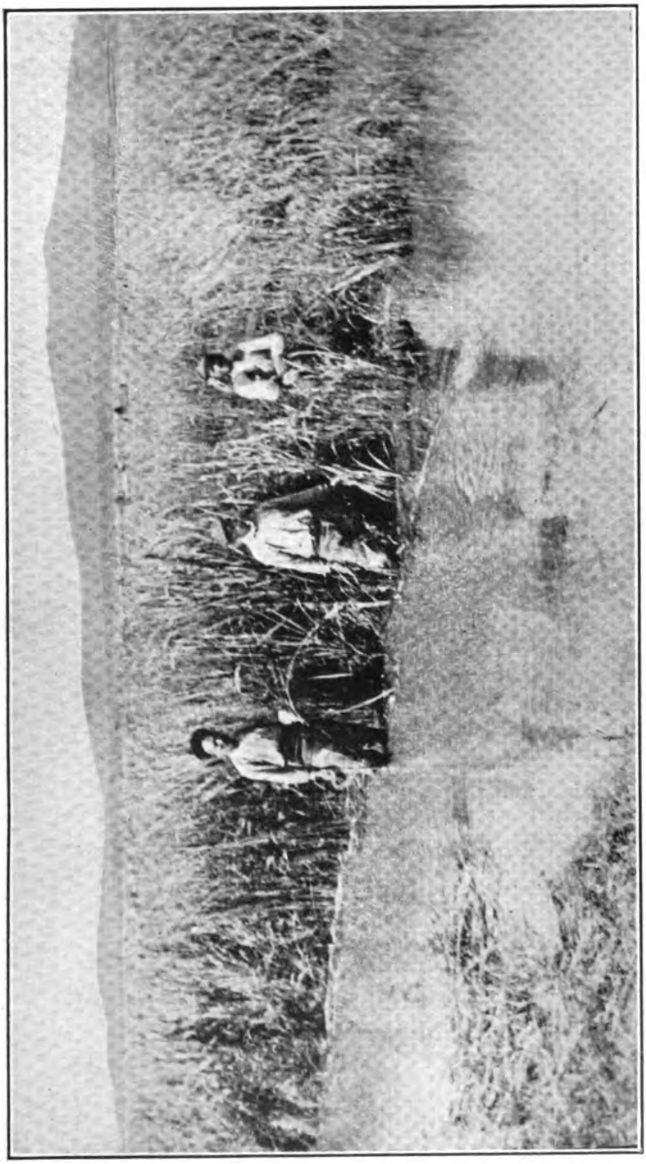


Fig. 7.—Labourers commencing to clear reeds in an extensive marsh.

principles of anti-mosquito work, but it gave opportunities of studying preventive measures and results under varying conditions of country and climate and established the soundness of preventive procedures.

Fig. 8.—View of a previously marshy nullah, cleared and canalized in 1917.

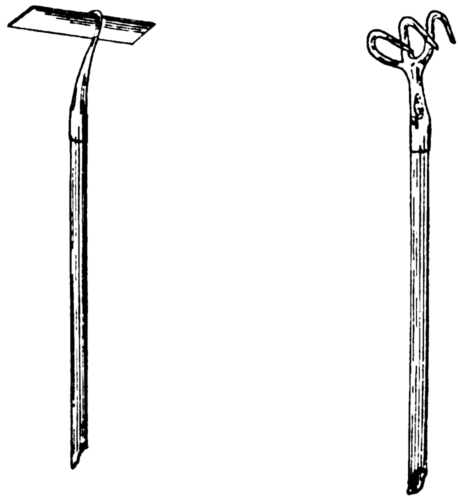
The mosquito was attacked directly in all stages of its existence—ova, larvæ, pupæ, and imagines; and indirectly its continuity was threatened by the removal of its breeding places.

Attack on imagines was perhaps developed more thoroughly under war conditions than had been previously carried out. The knowledge acquired of the habits of different mosquitoes enabled attacks to be made on them in their winter quarters, especially on the wintering adults of *Anopheles maculipennis*.

Fig. 9.—A wide sandy nullah showing channels being improved and re-cut in 1918. Condition of the old 1917 channel after the winter rains should be noted.

The actual winter quarters of this mosquito depended to some extent on the nature of the habitation of the people in the countries where it abounds. It selects in winter a situation where it will have a certain warmth, a sure source of occasional

food, shade, freedom from disturbance and shelter from draught. In England, stables, cowsheds, and pigstyes occupied by animals were the ideal winter home of *Anopheles maculipennis*. In the east of Europe the same is the case ; but there the mosquito is more closely associated with human beings, as many of the peasants are housed in the same building as their cattle, as was the case in England up to the end of the eighteenth



(*a*) (*b*)

Fig. 10.—The metal scraper (*a*) and the hook (*b*) are of special use in clearing algae and water weeds from the bed of a drain-channel or a stream.

century. The mosquitoes wander more widely and indiscriminately in the summer months but in the winter they could be destroyed in myriads by fumigation or by simply driving them out into severely cold and windy weather. In England the seasonal limewashing of cowsheds not only detected the presence of mosquitoes but effectually dislodged them. These measures of attack on imagines were emphasized in the years of the war.

In England the continued attack on *maculipennis* mosquitoes throughout one winter resulted in their almost complete absence during the following season in localities where previously myriads had existed.

Fig. 11.—A small rivulet, the bed of which was cleared of weeds and channelled, the edges being well built up with stones.

The methods of attack on ova, larvæ, and pupæ are various. Chemical treatment of waters has been employed by the use of many chemical disinfectants. Cresol in certain

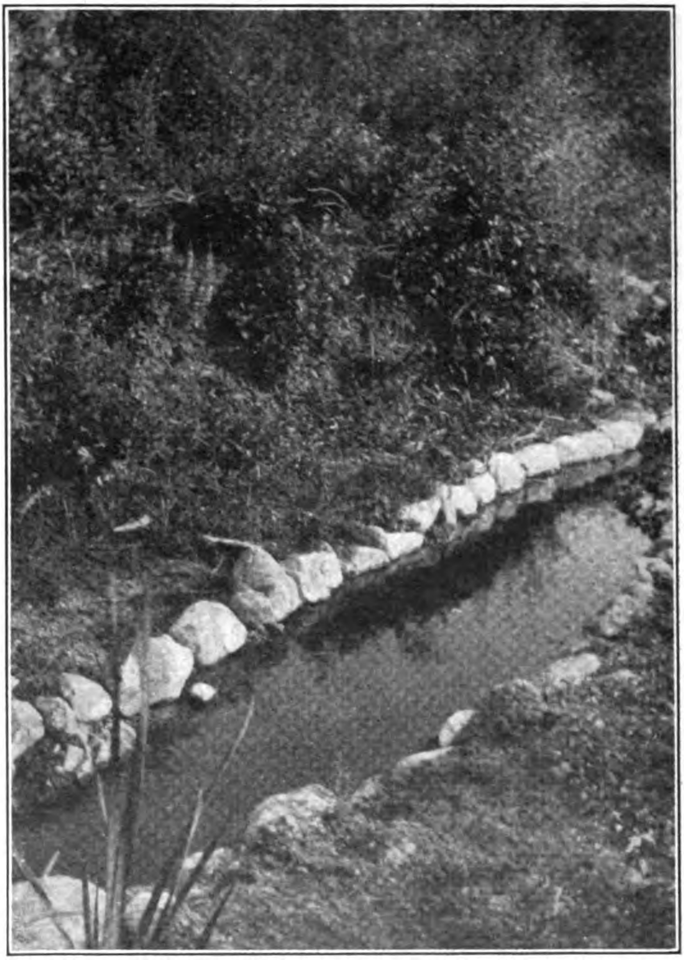


Fig. 12.—Example of stone-edged channelling in a grass-land stream.

dilutions has been found an effective larvicide, and was frequently used, chiefly because it was perhaps the most convenient disinfectant available. Oiling of waters was extensively

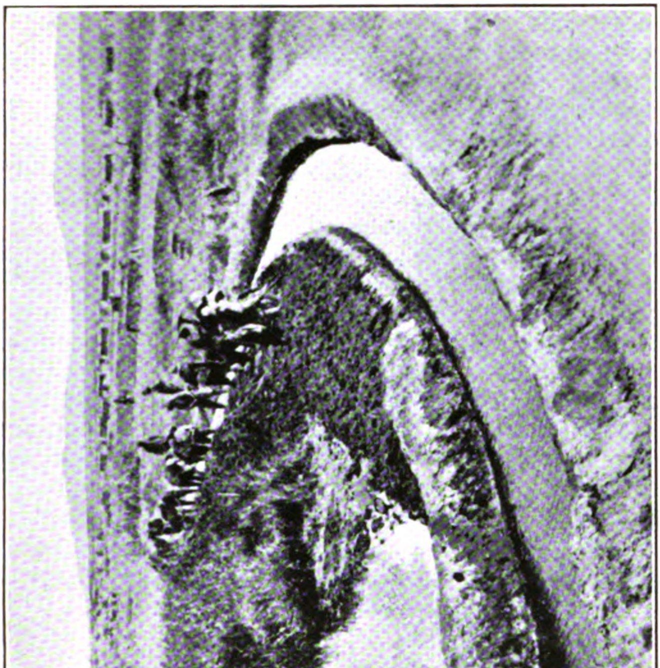


Fig. 13.—Making up the banks of a mill stream.

employed with the proved oils and emulsions, as well as with other oils and compositions, used on account of their economy, convenience, or supposed advantageous physical properties.

The great principle, however, which has long been established in the destruction of the embryonic mosquito, and which has been the main element of mosquito reduction during the war, was the conversion of real and potential breeding places into impossible or unlikely breeding places.

While the elimination of anopheline mosquitoes from unpopulated or sparsely populated areas with extensive areas for breeding is unnecessary, yet wherever the inhabitants of a malarial district are fairly numerous, the training of water-courses is a measure which is capable almost in itself of eliminating anophelines. It is also the most economical of all "anti-larvæ" measures. The training of watercourses consisted in the removal of the rank vegetation from their banks, and of the floating and subaqueous growth from the beds and channels, so as to leave them with clean-cut earth banks well above their normal high water, with clean earth bed and channel below the waterline, and without floating growth or débris. When this was done, most waters, which in their natural state were ideal anopheline breeding places, ceased to yield anopheline larvæ.

But without strict maintenance, by reliable labour, and under expert control the training of watercourses is likely to be ineffective. Efficiency can be determined by failure to find larvæ on any chance visit of inspection. In channels exposed to mosquito infestation from untreated waters, and in any case until local reduction has proceeded for some time, the least fresh accumulation of surface vegetation will usually yield larvæ.

The amount of labour required varied with the nature of the treated waters. A rough guide was to allot one man to one mile of ditch, gully, or stream whose banks and bed could be readily controlled from either side at the same time, the whole being gone over systematically once a week. With this arrangement no time is given for pupation or the emergence of imagines though eggs may be deposited and larvæ develop. Bank trimming, surface skimming, and bed clearing effect the early removal of ova and young larvæ, and the older larvæ and pupæ which may have escaped the labourer or the natural enemies. The great variety of water channels which had to be dealt with involved different details in treatment. The

ideal was the concrete conduit, and between that and the ditch with muddy banks and bed there was plenty of scope for individual ingenuity.

Oiling and chemical treatment were only occasional adjuvants to this method of treating waters. Most anopheline-bearing waters had first to receive the full training treatment before oiling was of any use, and to add oil was then only an unnecessary expense.

There were circumstances, however, in which, though other means might have been found effective, the experience of the war, in Palestine particularly, demonstrated the value of oiling. In the absence of other satisfactory methods, wells, cisterns, and reservoirs of stored water in which *Anopheles bifurcatus* larvæ are to be found the whole year round were treated by oiling, with good results. Great reduction of mosquitoes was effected, and the native populations realized the relief from mosquito infestation if not the ulterior benefit of improved health.

An aid to the treatment of water channels was the stocking of waters with "natural enemies," the most reliable of which are fish. The fish, which are of value as mosquito destroyers, vary in different parts of the world; and as was the case in war areas, suitable varieties were found in the areas under treatment. The bringing of fish from one part of the world to act as mosquito scavengers in another was unnecessary, expensive, and usually disappointing.

The removal of breeding places is chiefly affected by major engineering operations, although at the same time the anti-malaria work of an organized labour personnel is continually concerned with this, and is partly effected by the work of training the water channels. Major works were undertaken, especially in Salonika and Palestine, such as the drainage of marshes, swamps, lagoons; the filling in of swamps and low-lying areas; canalization; interception; salt-water flooding; clearing of bush and reed by burning or cutting down; and by diverse measures for reducing water surface to a minimum.

At the commencement of war the Army Medical Service had no specialist department or personnel concerned with malaria. It was early recognized that the malarious regions in Eastern Europe might prove disastrous to the health of the armies there, and personnel and material were devoted to all the phases of malaria investigation and prevention which have been detailed above.

A department of malaria practically existed at the War Office and a certain degree of co-ordination of research and control was obtained. Advisers and consultants visited the army fronts where malaria was present and personnel acquainted with the disease was utilized where needed. Still, with the exception of the regular R.A.M.C. officers, most of whom had much experience of malaria in India or elsewhere, many officers with special reserve, territorial, or temporary commissions had their first experience of malaria during the war.

The loss of strength to the armies from the effects of malaria was great, and but for the preventive methods adopted it might have been incalculably greater.

CHAPTER IX.

PREVENTION OF CEREBRO-SPINAL FEVER.

AT the end of 1914, when it became evident that cases of cerebro-spinal fever were occurring among the troops in the United Kingdom, the commands were asked to furnish a list of cases which might be considered as cerebro-spinal fever. From these lists it was clear that the disease had broken out in the Eastern Command at Shorncliffe, in the Scottish Command, at Aldershot, and in the Southern Command, principally among the Canadian troops, on Salisbury Plain. On 4th January, 1915, at the request of Colonel Carleton Jones, D.M.S. of the Canadian contingent, and by the direction of Sir Alfred Keogh, D.G., A.M.S., Colonel Horrocks and Lieut.-Colonel G. S. Buchanan of the Local Government Board visited the Canadian camps accompanied by Dr. Mervyn Gordon, who advised on the bacteriological aspects of the situation. On the following day they held a conference at Whitehall, and the question as to what useful procedure could be adopted so far as bacteriological work was concerned was discussed with Lieut.-Colonel Nasmyth, C.A.M.C., and Dr. Arkwright, who was employed by arrangement between the Canadian authorities and the Lister Institute to conduct the bacteriological investigations. At the meeting of the Army Sanitary Committee on 12th January, 1915, the reports from the commands and a report by Colonel Horrocks and Lieut.-Colonel Buchanan on cerebro-spinal fever among the troops of the Canadian contingent camped on Salisbury Plain were discussed, and the committee recommended that Surg.-Colonel R. J. Reece, then attached to the Honourable Artillery Company, who had had considerable experience under the Local Government Board in the conduct of inquiries into this disease, should be seconded with a view to the utilization of his entire services in connection with the various outbreaks then under report, and any others that might occur.

Surg.-Colonel Reece joined the War Office on 15th January, 1915, and after short visits of inquiry to the affected areas drew up, under the direction of Colonel Horrocks, a scheme for the administrative control of cerebro-spinal fever which was at once put into operation. As it was evident that the control,

to be effective, must take account of occurrence of cases of cerebro-spinal fever among the civil population, by the courtesy of the Medical Officer of the Local Government Board Colonel Reece resumed his work there so far as dealing with the disease among the civil population was concerned,* and received notifications of all civilian cases and a report on each case by the Medical Officer of Health in whose district it occurred. It was thus possible to keep in constant touch with all cases, civil and military, occurring in England and Wales. By the courtesy of the Local Government Boards of Scotland and Ireland, information of cases occurring among the civil population in these countries was forwarded to Colonel Reece at the War Office.

Medical officers in charge of troops were required to notify by telegram to the War Office each case as it occurred, in addition to notifying the case to the D.D.M.S. of the Command. The cases were duly registered and later a card index was also kept. Registers were also carefully kept showing the details of cases that occurred in camp, barrack, or billet, and in each regiment. By these means it was possible to trace the history of occurrences in any particular camp or in units as they changed quarters, and to arrange for inquiry into particular occurrences.

A specimen of the card used for each case is reproduced in Appendix B, 1.

The Central Laboratory.—A central laboratory was established at the Royal Army Medical College in London for investigation, research, and instruction purposes, and Dr. Mervyn Gordon, Assistant Pathologist of St. Bartholomew's Hospital, who had done special work in regard to the bacteriology of cerebro-spinal fever, was appointed consulting bacteriologist in charge of the laboratory. Dr. Gordon was granted the honorary rank of Major, and later of Lieut.-Colonel, in the R.A.M.C., and the Medical Research Committee of the National Health Insurance Commissioners undertook to pay for his services. Later the laboratory was moved to the Medical School of the Westminster Hospital, where more commodious quarters were available. In this laboratory the media for cultivating the meningococcus were prepared and distributed to the different bacteriological laboratories in the several commands. This work of preparation and distribution was in the special

* In all instances where reference is made in this account to the civil population, it relates, unless the contrary is stated, only to the civil population of England and Wales, with which countries the Local Government Board was solely concerned.

care of Dr. T. G. M. Hine, who was granted the honorary rank of Captain, and later of Major, and whose services were paid for by the Medical Research Committee. Few bacteriologists at that time possessed special knowledge or experience of the meningococcus; selected bacteriologists were, therefore, sent to the laboratory for instruction and the staff were always available to discuss any technical points arising, and to assist other official workers. Laboratory assistants also received special training at the Central Laboratory.

Division of the Country into Administrative Areas.—Some forty special bacteriological laboratories, available for purposes of diagnosis, etc., were established in the several commands in England and Wales, and others in Scotland and Ireland and in the Channel Isles at Jersey. So far as was found practicable, existing laboratories were utilized and subsidized. The bacteriological laboratories of the universities of certain counties and the municipal bacteriological laboratories of some large towns afforded special facilities, as they already possessed the necessary accommodation and trained staff; in a few instances use was made of private laboratories. In most of these cases the professional staffs received grants from the Medical Research Committee in aid of their special work.

The value of the assistance and co-operation of the Medical Research Committee cannot be over-estimated.

Where civil laboratories were not available, either the bacteriological laboratories of certain military hospitals were adapted for the work, or a military laboratory was newly established and a military staff installed. In making these arrangements, due regard was paid to the requirements of the expanding army and to the possible distribution of the troops in the future, and only minor alterations had to be made at a later stage. In addition to the cerebro-spinal fever work, the greater number of these laboratories carried out the ordinary bacteriological work of the district; comparatively few dealt solely with cerebro-spinal fever. Some little difficulty was experienced in Scotland and Ireland in arranging for laboratories to be available for the troops, as in these countries small bodies of troops were stationed in places not well supplied by railways, and it was not always an easy matter to get the material taken from the patients promptly delivered for examination in the laboratories. The whole country, however, was divided up into areas, and in each area there was a laboratory which dealt specially with cerebro-spinal fever. The bacteriologist of this laboratory dealt with

the cases of cerebro-spinal fever that occurred in the area served by the laboratory, and with the contacts of such cases. He or his assistant, or some duly qualified person acting for him, swabbed the patients and the contacts, and for each area an officer was appointed to keep the records of each case and to make enquiries concerning the circumstances in which the case occurred.

As soon as it became known that cerebro-spinal fever was present among the Canadian troops, a special bacteriological laboratory was established on Salisbury Plain to deal solely with the malady occurring among them. It was staffed by Canadian medical officers and placed under the direction of Dr. Arkwright, of the Lister Institute. The operations of this laboratory were continued until such time as the Canadian contingent went overseas, when the laboratory accompanied it.

Motor Laboratory.—In order to meet emergencies a motor bacteriological laboratory, specially designed for the work by Lieut.-Colonel Mervyn Gordon and Major Hine, was fitted up and placed in charge of the latter officer. A laboratory assistant was appointed for duty solely with the laboratory. This travelling laboratory proved most useful in the early years of the war; it was despatched to places where the local staff was inadequate to deal with the number of contacts, or where the bacteriological laboratory was not easy of access. It was available also to afford assistance of a confirmatory character on occasion. On such duties it was sent to Devonport, Avonmouth, Southampton, Dover, Scotland, and other places. It was found of special value within London and in its immediate neighbourhood.

Issue of Memoranda on Cerebro-spinal Fever.—Memoranda "on the procedure to be adopted on the occurrence of a case of cerebro-spinal fever" and a "Memorandum of cerebro-spinal fever in military camps" were drawn up and issued on 25th February, 1915. Later, in May 1916, these memoranda were revised and issued as a single document, and a further revise was made in March 1917. Finally the memorandum was again revised in March 1920, and this last edition embodies the experience obtained during the war.

The memorandum of the Local Government Board on cerebro-spinal fever was revised and re-issued with a covering letter to all sanitary authorities and medical officers of health on 22nd February, 1915, and it was subsequently again revised in August 1918.

Staff of District Laboratories.—At first the bacteriologists appointed to the laboratories, other than those of the universities and large towns, were picked men specially recruited for the purpose. There was a shortage of trained bacteriologists, and before long the demand for them for service overseas resulted in many of the officers originally selected for cerebro-spinal fever work being drafted to the army abroad. Their places were filled as far as possible by men who, for one or another reason, were unfit for general service or had returned wounded or sick from overseas. Each summer the bacteriologists of the laboratories were required to furnish a report on the working of the laboratory. The general scheme of the report was outlined, and the points on which information was required were indicated, while the bacteriologist was invited to place on record such of his observations as might be of interest. (Appendix B, 2.)

It sometimes happened that the bacteriologist who had been in charge of the laboratory during the busy period of the year had left for overseas service before the report was prepared, and in such instances the reports lacked the impressions of the actual worker. All the reports were considered at the War Office and at the Central Laboratory with the object of checking the working of each laboratory and obtaining information that could be made of general use, and certain selected reports were circulated to other laboratories. In instances where the bacteriological results obtained at a laboratory differed from those at similar laboratories, the matter was investigated on the spot by one of the staff of the Central Laboratory.

Work of Special Staff at the War Office.—In December 1915 Captain F. Seymour, R.A.M.C., Medical Inspector of the Local Government Board, was attached to the War Office. Later, in June 1917, he was selected for the appointment of Specialist Sanitary Officer to the Eastern Command, when he was succeeded by Captain R. Bruce Low, who had had special experience in public health work in the Malay States, and in March 1918 Major Fegen, the medical officer of health of several sanitary districts in Surrey, was also attached to the War Office; the two latter officers had both been invalided from overseas. They were available for visits of inspection and inquiry to camps or to places where troops were billeted and where cerebro-spinal fever exhibited epidemic prevalence, and they were able to advise and assist officers engaged in coping with the disease. The efficiency of the civil public health service was diminished owing to civil medical officers

of health having gone on military service. The medical officers doing duty with troops were mainly recruited from civil medical practitioners who had not the advantage of the military medical training which the regular medical officers of the army had received. Nevertheless, the rapid way in which many of these officers acquired a knowledge of military hygiene was remarkable.

Although visits made to camps and other localities by the War Office staff were primarily concerned with outbreaks of cerebro-spinal fever, they were not solely restricted to these matters. It was recognized that the general sanitation of the camp was a matter that could not be disregarded, and in cases where sanitary defects were observed, the attention of the specialist sanitary officer of the camp was called to them with a view to their improvement. In matters of more urgent importance the facts were reported to headquarters for consideration. So far as possible nearly all camps and barracks were visited at one or another time, so that in the event of cerebro-spinal fever breaking out among troops at any place, the general arrangements of the locality and the personnel were known, and any necessary action could be taken.

Appointment of Specialist Sanitary Officers.—One important step was the appointment of the specialist sanitary officers of commands to be supervising officers for all matters relating to cerebro-spinal fever in their command. From time to time these officers were summoned to conference at the War Office when points of general interest were discussed, and in this way knowledge of the disease was diffused and uniformity of action secured.

Treatment of Carriers.

At first all known contacts of clinical cases of the disease were segregated and their throats swabbed. Those furnishing a negative result were discharged to duty ; those certified to be positive were retained for treatment. The latter were segregated in a particular hut or tent and were encouraged to value exercise in the open air. The treatment consisted of insufflation and gargling with a solution of permanganate of potassium, or hand spray atomizers were used. The central laboratory was working out the types of meningococcus and little detailed work was at that time devoted to the study of the "carrier" question.

The Evolution of the Steam Spray Method of Treatment.—Early in 1916 Colonel Reece called the attention of Major

Gordon to a report, an abstract of which he had seen in a Swiss paper, wherein it was stated that by intensive local disinfection of the naso-pharynx it was possible to control an epidemic of cerebro-spinal fever; a preparation which liberates chlorine had been improvised and used in spray form with great success in the Fortress of Cologne. Not having access to the original paper, Colonel Reece was unable to say what sort of apparatus and what preparation of chlorine were used, but suggested that the matter might be worth trial on chronic carriers. Colonel Martin Flack,* at that time the bacteriologist of the London District, investigated this matter, with the result that the Levick† steam spray was designed by the staff at the central laboratory. This apparatus is portable, and by means of it a finely atomized spray charged with a disinfectant is thrown into the atmosphere so that it is not possible to see across a small room. The rate of spraying to effect this result is 1 litre of antiseptic sprayed in the course of twenty minutes in a chamber of 1,000 cub. ft. Many antiseptics were tested, the best results being obtained with chloramine T. and sulphate of zinc. The former appeared to be the more effective, but at times it was said to produce giddiness and accelerated action of the heart; the latter is cheaper and it was thought that less untoward symptoms followed its use. These Levick steam sprays were supplied to the commands as required. Being portable they could be sent to places where spray treatment was required and they could be used in small barrack-rooms or huts specially fitted for the purpose. Undoubtedly they were effective when properly used, but the reports on their use showed divergent results. Investigation into the causes of unsatisfactory results showed that the men submitted to the treatment were overcrowded in the spray chambers, or that the apparatus was not working properly.‡ The action is not unlike that of the Primus stove and the fine jet point is apt to get blocked, and requires careful cleaning. On one occasion when the reports on its use showed that it was ineffective, the circumstances were investigated by Captain R. Bruce Low. The antiseptic employed was sulphate of zinc and the water was a hard chalk water. Captain Bruce Low found that a chemical action was taking place and an insoluble carbonate of zinc formed which

* His services were supplied by the Medical Research Committee and he had been given honorary rank in the R.A.M.C.

† So called from the name of the manufacturers who made the first sprays; it is a modification of the Lingner sprayer.

‡ *Vide* p. 251.

blocked the tubes, and only steam uncharged with an antiseptic was emitted from the apparatus. When rain-water, or water that had been previously boiled, was substituted the results obtained were more satisfactory.

The sprays are fitted with a methylated spirit lamp, although the water can be heated by a Bunsen flame when gas is available. A drawback to the apparatus is that although the boiler is made of copper, the metal stand which holds it is made of iron, and the ironwork rapidly perishes when the apparatus is in constant use. It was found necessary to have the sprays returned to the central laboratory from time to time, where they were examined, necessary repairs made, and each apparatus tested for efficiency before it was re-issued. A further drawback to the Levick spray is that it throws out a great deal of heat and the temperature of the spray chamber becomes very high. When the external temperature is low there is always the danger that men coming from the hot chamber may contract colds. Further, it could only be operated for a limited number of minutes, after which it required re-charging. The latter difficulty was overcome to a certain extent by having more than one apparatus, so that when one ceased to work another could be put into action.

Attempts were made to utilize the advantages and to minimize the disadvantages of the Levick spray. At Aldershot, Captain Lundie, the bacteriologist in charge of the laboratory, designed an apparatus which was capable of being in action for a longer period than the Levick spray. Valuable assistance was rendered by Lieutenant E. Gordon, R.E., in the experiments undertaken at the central laboratory; these showed that it was possible to generate steam from a small boiler, and that by placing the boiler with its furnace outside the spraying chamber, undue heat in the chamber could be avoided. Major Hine designed a nozzle or jet by which the introduction of steam and antiseptic could be regulated, and these jets were attached to pipes carrying steam from the boiler to the chamber. An experimental chamber was set up at the Guards' Depôt at Caterham, and as it proved of great value in dealing with carriers at that station the principle was adopted for use elsewhere. There was, however, a difficulty in obtaining boilers, and this limited the use of these spraying huts. The advantages, in addition to the absence of undue heat in the chamber, were that a larger chamber could be utilized, the size depending on the amount of steam available and the number of jets, and in consequence a larger number of men could be

submitted to the spray treatment at one time, and the spray hut could be kept in operation for several hours at a time. It was found desirable, however, to arrange for a thorough blow through of air before the introduction of fresh batches of men.

Whereas the Levick spray was more generally operated from the ground-level and the steam driven perpendicularly into the air, by Major Hine's arrangement the steam could be introduced at a level of about 5 ft. from the ground and directed slightly upwards. The antiseptic fluid was placed in jars from which it was sucked up by the flow of steam, and it was possible to regulate the amount of antiseptic discharged into the atmosphere in a given time.

Mobile Steam Spraying Apparatus.—The disadvantage of the spraying hut with the fixed boiler was that it was a permanent erection. Even in Caterham, as the depôt extended, some men had to march a considerable distance to receive treatment. In the commands it was not an easy matter to decide at what spot such a spraying arrangement could best be placed and be available for the general use of the command.

At this time Colonel Horrocks was designing portable apparatus for the disinfection of clothing, and it occurred to him that a portable spraying apparatus might be designed, steam-driven lorries utilized, and the steam supplied from the boiler of the engine. Enquiries were instituted and it was found that such lorries were not available and that it was easier to obtain the ordinary motor vehicle. It was part of Colonel Horrocks' plan that the vehicle should carry all the apparatus required, and that a small marquee could be used as a spraying room, another as a waiting room for the men, and a third marquee as a "cooling-off" room during inclement weather. The general scheme was submitted to Lieut.-Colonel Rudd, of the Ordnance Corps, stationed at Aldershot, and permission was obtained to construct two experimental vehicles. Colonel Rudd procured two small high-pressure boilers, one of the type used on the Stanley steam car and the other of the Merryweather type used on fire-engines. The former was the smaller and lighter apparatus, but the supply would have had to be procured from America, and this was impracticable; also it required a higher intelligence on the part of the mechanic in charge than was necessary in the case of the latter. The Merryweather type was more easily available and quite efficient in its working. Colonel Rudd fitted an arrangement to these engines by which the furnace could be put into working order in a few

minutes by means of a small manual air-pump and cylindrical pressure reservoir which was piped to the fuel injector. A two-way cock was supplied for cutting off the air pressure and admitting steam from the boiler when steam was available.

Two old motor-car engines were acquired and repaired by Colonel Rudd, who also designed and fitted a carriage capable of carrying the necessary apparatus, a portable steam spray apparatus which could be used inside a marquee, barrack-room, or hut, and devised a nozzle or jet which could be easily cleared of obstructions. It was considered that the marquee, being canvas, would allow of the escape of an undue quantity of steam, but in practice the reverse was the case; the marquee gave even better results than the fixed huts. These experimental plants were tested from the practical side with satisfactory results. Figs. 1 and 2 show the general arrangement of the plant and the apparatus used in the steam jet.

Fig. 1 shows the mobile steam spraying equipment. Steam, generated by a "Merryweather" boiler, is conducted by a flexible pipe to rigid pipes fitted with Hine's jets, and terminating with a "blow off" tap. The steam pipes are supported on tripods which are fitted with a tray to hold the jar containing the disinfecting solution. The arrangement of the tripods shown is that suitable for the interior of a hospital marquee, small hut, or barrack-room. The tripods, steam pipes, etc., are readily detachable and capable of being packed in a small space, and together with the marquees are carried in the van of the motor vehicle. In addition to its use for the disinfecting steam spraying of contacts of cerebro-spinal fever and other diseases, in which infection is acquired through the naso-pharynx, such as measles and mumps, the apparatus was used for the destruction of mosquitoes and flies in barrack-rooms, etc.

Fig. 2 shows the steam pipe fitted with a Hine jet and terminating in a "blow off" tap, supported by a tripod. The jar containing the disinfecting fluid stands on a tray fixed on the tripod. An india-rubber tube conducts the disinfecting solution to the Hine jet; a glass tube insertion allows the flow of the disinfecting fluid to be observed. The amount of steam driven through the jet can be adjusted so that the measured contents of the jar are evacuated in a given time, the number of jets used being determined by the cubic capacity of the "spraying chamber" or marquee.

The experimental plants were employed in connection with the arrival of troops from dominions overseas and sent to places where spray treatment was considered necessary. They were also used to supplement the spraying facilities at Caterham, and in the Scottish Command. One disadvantage of this portable apparatus was that it took up the whole time of two trained men. One man was in charge of the spraying apparatus, while the second trained man was a motor driver attached for duty from the Royal Army Service Corps Mechanical Transport. There might, however, be a compensating advantage in having two men attached to each "plant," because one could relieve the other, as exposure to the steam spray for long periods at a

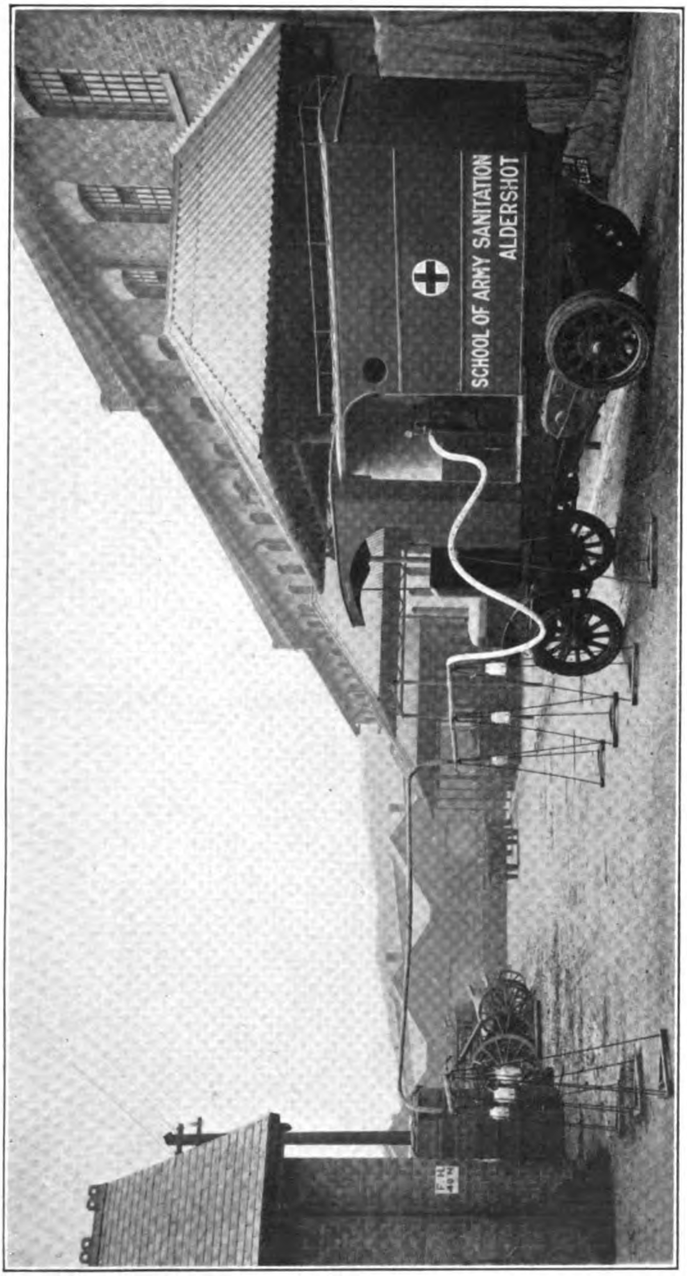


Fig. 1.—Mobile steam spraying equipment.

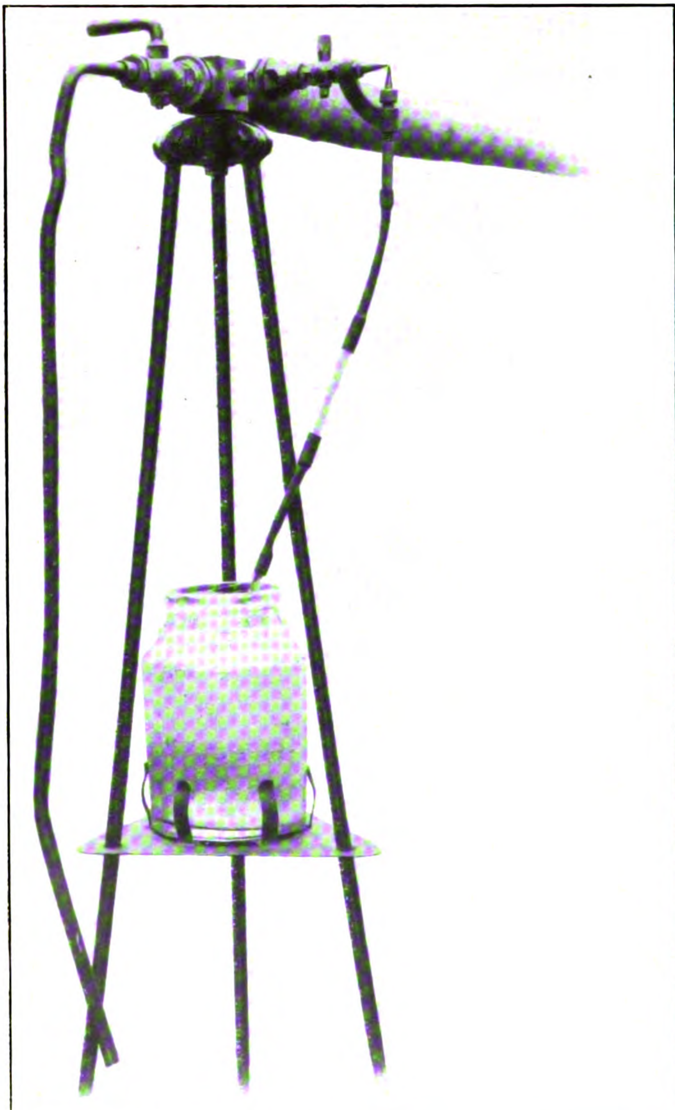


Fig. 2.—Steam spraying apparatus.

time, necessary to regulate the action of the jets and to see that neither too little nor too much antiseptic was used by irregular working of the jets, prejudicially affected the operator. With

regard to the motor driver, it must be explained that according to regulations such drivers are attached for duty to a particular motor vehicle, for the driving of which they are responsible and which they must not leave. This necessitated the driver remaining by the vehicle for as long as three weeks at a time when it was stationary in a camp. To prevent this waste of trained man-power an apparatus was designed on the principle of a trailer which could be attached to a motor or horse-drawn vehicle, or put on rail for conveyance to any place where it was wanted. An order was placed for a certain number of these trailers for use in the several commands, but there was a delay of several months in their delivery and the first instalment was not received until after the armistice.

In practice it was found that three marquees were not necessary. It was possible for the squads who were to receive treatment to be marched to the spraying marquee at a given time and to enter it at once for treatment. Except in very inclement weather the third marquee for "cooling-off" is unnecessary, as the men on leaving the spraying marquee can be taken for a short brisk march. The collection of men in a confined space after spraying is undesirable.

Experience of Steam Spraying.—When the spraying chamber was first introduced the value of a constant change of atmosphere was not realized. In one command an order was issued for a couple of detention cells of a regimental guard-room to be made practically air-tight so that they could be utilized as spray treatment rooms for the men of the unit. When the spraying chamber was first fitted up at Aldershot, it was soon found undesirable for carriers undergoing treatment to be in an atmosphere under conditions which necessitated their breathing the same atmosphere again and again, although this was charged with an antiseptic. To ameliorate this, ventilation was secured in spraying huts by allowing a certain amount of the steam to escape, and in marquees by keeping the ventilators open. It was realized that men subjected to the spray treatment should breathe vigorously through the nose and mouth, and the attempt was made to teach the men to inhale the atmosphere charged with steam. The physiological effect of introducing men into a chamber so densely filled with atomized steam charged with an antiseptic which could be tasted had to be reckoned with. These men were also undergoing "anti-gas" instruction, and the effect of poisonous gases was a very real matter with them. The result was that a certain number of men fainted when standing still in the chamber, a not uncommon

occurrence with men on parade in trying circumstances. To obviate this, the men were kept moving round the chamber, but experience showed that this method could be improved, as the men tended to collect together in groups. Finally, it was arranged that the men should be seated on benches facing opposite ways, and, on the suggestion of Colonel Horrocks, each man was allowed 27 sq. ft. of space. Under these conditions the men could not breathe on one another, and men did not drop in a fainting condition when seated. Experience afforded ample evidence that when men were crowded at one time into the spraying chambers, the desired effect was unlikely to be attained. There was also a distinct possibility, under crowded conditions, of infection being transmitted in the spraying chambers. The variations of practice in regard to the number of men admitted to the spraying chamber at one time may have been, and probably were, responsible for the divergent results attained. It is not possible to state with any degree of certainty the result that may be expected to follow the use of steam spraying chambers charged with an antiseptic; it is possible to say that this procedure appeared to have beneficial results of sufficient importance to warrant the application of the method, under conditions which have been evolved, to the treatment of troops exposed to infection of cerebro-spinal fever. Further, such treatment might be extended to other diseases, the infection of which is acquired through the naso-pharynx, such as scarlet fever, measles, and mumps. When dealing with diphtheria carriers the result has been disappointing, and the inherent difficulties associated with influenza are such that further experience and knowledge are required before any pronouncement can be made with regard to antiseptic spray treatment of this malady.

Installation of Steam Spraying on Transports.—The incidence of cerebro-spinal fever among troops was not limited to the United Kingdom; cases occurred also in troops in camp in the overseas dominions, and the first Canadian contingent to arrive in this country brought the infection with them. Similarly, Australian and New Zealand troops suffered on the voyage, apparently through carriers. This matter was taken up by the New Zealand medical staff, and after consultation with Colonel Reece and Lieut.-Colonel Gordon an arrangement was arrived at by which troopships leaving New Zealand should be fitted with a spraying apparatus based on Major Hine's principles and troops should undergo spray treatment for at least the first fortnight of the voyage. It was part of

the scheme that the troops should be swabbed before embarkation, and only those giving negative results should be embarked. This was a comparatively simple matter so far as New Zealand was concerned, as the troops were numerically few and the executive staff and medical officers concerned were keenly alive to the desirability of embarking only those men who were free from meningococcal infection. The result was entirely satisfactory. It was otherwise with Canadian and Australian troops, as the number to be reckoned with was much larger, and the importance of only embarking troops free from meningococcal infection was subservient to that of placing these troops at the earliest possible moment in the fighting line. Arrangements, however, were made to instal the spray treatment on transports, the steam being supplied in most instances from the steam pipes of the vessel. The occurrence of cerebro-spinal fever on transports is referred to later.*

Comparison of Military and Civil Administration.—In the early months of 1917 anxiety was caused to those who were watching the course of the disease by the fact that the actual number of military cases notified was larger than in either of the previous two years. It was said that recruits joining the army showed an increasingly high carrier rate, and in consequence that the troops were being infected by those joining the ranks from the civil population, and doubt was expressed as to the efficacy of the means employed to control the prevalence of the disease among the civil population.

As shown elsewhere in this account, the proportion of attacks to the number of troops serving was lower in 1917 than it was in 1915, although the actual number of notified cases was larger; the circumstances associated with this occurrence are dealt with later. In order to obtain a true estimate of the proportion of carriers among recruits joining a depôt from the civil population it would be necessary to examine each man on arrival before he had mixed, even for a single night, with soldiers in a depôt. Recruits examined at a depôt in which it was known that there was a high carrier rate might be expected to show a somewhat similar carrier rate if they were examined some days after their arrival. In one instance when an examination of recruits was made at a depôt 20 out of 27 recruits examined were returned as positive. On investigation it was found that the shortest time that any one of these 27 recruits had been in the depôt was fourteen weeks and

* *Vide* p. 275.

five days. It was not surprising that the fallacy crept in in this case, as at that time recruits joining the colours were submitted to intensive training and sent overseas as trained soldiers within a few weeks of their joining the army. The depôt in question, however, was a Guards' depôt, and a high state of efficiency was still required of a trained soldier in the Guards, and the length of the period occupied in training their recruits had not altered materially from pre-war conditions.

As shown elsewhere,* the distribution of cerebro-spinal fever among the civil population closely approximated to the distribution of the troops, and many instances are recorded in which the disease was introduced by soldiers returning to their homes. The conditions under which the troops lived favoured the spread of the infection from person to person, and dominated the prevalence of the disease among the civil population.

There is no doubt that in the first three months of 1917 the carrier rate in the civil population rose above the average rate, but no exhaustive attempt was made to ascertain this, and even had such an attempt been made, and the presence of a high carrier rate found, it could not have been subjected to comprehensive measures of administrative control.

The methods of procedure adopted in the civil and military populations respectively for the administrative control and prevention of the disease were closely allied. In both instances cases of the disease were compulsorily notifiable. They differed in so far as soldiers were under military discipline and their movements were controlled by authority. The civil population was under no such control.

The chief points in the memoranda drawn up by the central authority, military and civil, can be shown in parallel columns :

Military.	*Civil.*
The confirmation of the clinical diagnosis of each case by a military bacteriologist is arranged for.	The Local Government Board advise that the most reliable means for determining the cause of the disease consists in the examination by a competent bacteriologist of the cerebro-spinal fluid withdrawn by lumbar puncture, and the Board undertakes the examination of such fluids submitted to the Board's bacteriologist. The result of the examination is telegraphed to the medical officer of health concerned.

* Report of the Medical Officer of the Local Government Board 1917–1918 and Report of the Medical Department of the Local Government Board 1918–1919.

Military.	*Civil.*
A military case is to be isolated in hospital.	Isolation in hospital is recommended by the Board. There is no legal power to compel the isolation in hospital of the infectious sick in the civil population unless under order of a magistrate.
Disinfection of the patient's urine, clothing, bedding, feeding utensils, and quarters.	Disinfection of the patient's throat secretions, towels, handkerchiefs, clothing, bedding, and feeding utensils, and of the sick room, etc.
Contacts :— Segregation. Examination for carriers. Disinfection of naso-pharynx of contacts. Segregation of carriers.	Contacts :— All persons in attendance or in close personal association with the patient should be regarded as possible carriers of infection and warned that they may be a source of danger although remaining well themselves, and that for this reason they must abstain from intimate personal association with others. Disinfection of the naso-pharynx of contacts is recommended.
Investigation of cases by a specially appointed medical officer.	The special attention of the medical officer of health is directed to investigation of sources of infection.
A report on each case is furnished to the War Office.	The medical officer of health furnishes a report on each case to the medical officer of the Local Government Board.
Notification of each case to the War Office, headquarters of the command, assistant director of medical services, civil medical officer of health.	The disease is compulsorily notifiable in the civil population to the medical officer of health, who furnishes a weekly return to the Local Government Board and County Council and is directed to notify each case to the medical officer in charge of troops in the district.

It must be remembered that the civilian is under different administration from the soldier. There is no legal power compulsorily to examine contacts or even the patient. The treatment of the patient is entirely in the hands of the general practitioner unless the patient is removed to an isolation hospital, where he comes under the charge of the medical officers of the hospital. The medical officer of health can warn a family of the danger of contacts and carriers and advise as to their movements; he has no power to compel isolation of contacts and carriers, he cannot insist on the disinfection of the naso-pharynx of a contact. Nevertheless, the influence of the medical officer of health is such that he can in large measure succeed in getting this done.

The difficulty in arranging for the examination of swabs from the naso-pharynx of contacts in the civil population is partly due to the short life of the meningococcus under adverse conditions and to the fact that examination of swabs sent by

post is useless. To be of value a swab should be plated out as soon as it is taken and the plate kept warm until it can be placed in the incubator. In civil life bacteriologists are not available for this work in country districts and certain small towns, and even in large towns the amount of bacteriological work that could be done in 1917 was limited owing to the bacteriologists and laboratory attendants having joined the army. The local public health staffs were depleted from the same cause, as medical officers of health, inspectors of nuisances, and clerks in the local sanitary offices had been summoned to the army. There was much deputy work being done by men who had had no previous administrative experience in public health work, and in small districts and in the country this was frequently done by overworked general practitioners. For these reasons no systematic attempt could be made on a large scale to ascertain the local carrier rate among the civil population, although attempts were made in a large number of cases to detect carriers among contacts.

It is known that the bulk of contacts who are shown to be carriers free themselves in a short period—probably in about three weeks. In all probability it is the chronic carrier who spreads the disease, and principally at times when he is suffering from catarrh. The treatment of soldiers in camps and barracks, where on a sample swabbing the carrier rate was found to be high, could be dealt with by means of the steam atomizer. The civil population was not provided with steam atomizers, and even if local authorities set them up they had no power to compel contacts to submit themselves for naso-pharyngeal disinfection.

This treatment was still in its infancy, and its full value has even yet to be determined. So far it appears to have given good results in the army. It is, however, treatment undertaken *en bloc* and it is done with the view to freeing such carriers as may be present among those submitted to the action of the disinfecting spray. The effect is to be judged by the absence of fresh acute cases and by making bacteriological examination of a " sample " of the men.

It was suggested that a serious attempt might be made to eradicate carriers from the population during the summer months when the carrier rate is presumably very much lower than in the winter. If it be granted that the number of positive carriers is less in the summer months than in the spring, the actual number of carriers to be isolated would be less in the summer than in the spring. The number of persons to be

examined bacteriologically would, however, be the same, for until a man had been examined it would not be possible to say whether he was a carrier. The work of the bacteriologist would, however, be less in the summer than in the winter, as he would have a greater number of negatives to deal with.

The work of undertaking a bacteriological examination of swabs from the naso-pharynges of the population of even a moderately large town would be very great, and to get the result aimed at it would be necessary to segregate the population after swabbing until the result of the swabbing was known. For it is manifest that if persons were permitted to move about and pay visits, travel by train, tram, or omnibus, a person who was negative when swabbed might really have been infected before the negative result was obtained from the bacteriologist. If this assumption is correct, then it would follow that all those examined should be kept apart from others until the result of the bacteriological examination is known, and when known to be negative, such negative person should not associate with any unswabbed person, lest he become infected. Even if legal powers existed to enforce this procedure it could not be put into operation; the civilian population would not submit to it.

The medical staff of the Local Government Board was depleted and overworked and unable to deal with the public health circumstances of the country as it formerly could in peace times. There was no staff available to send to local places where a case or two of cerebro-spinal fever occurred.

There is no legal power by which the recommendations of the Local Government Board's memorandum on cerebro-spinal fever can be enforced either on the local sanitary authority, the medical officer of health, the civil general practitioner, or the public. Therefore, when considering the problems associated with the carrier condition, it must be understood that more effective control can be exercised over the military than over the civil population and that for practical purposes the movement of the latter cannot be controlled. In the former the movements of the individual can in great measure be regulated by authority, and this is of primary importance, inasmuch as the liability of certain infections to spread, once they are introduced, is much greater in the military than in the civil population.

Incidence of Cerebro-spinal Fever on the Military and Civil Population.—A study of the notification returns shows that at times more cases of cerebro-spinal fever occurred in the military

population than in the civil, notwithstanding the fact that the number of civilians in the United Kingdom can be considered as more than twenty times as great as the number of soldiers. This heavier incidence amongst the military population was especially noticeable during March and April 1917, and again towards the end of 1918.

While it is probable that infection was carried at times from the civil population to the troops, yet when dealing with a disease like cerebro-spinal fever, in which spread of infection is largely dependent on close aggregation of persons—a factor peculiarly associated with the conditions under which the soldiers lived, among whom there was special incidence of the disease—it follows that it must frequently have happened that the infection was carried from barracks and camps by individual soldiers to the civil population. The desirability of obtaining effective control over the military carrier was evident, both in the interest of the civil population and of the troops. The endeavour to discover the best method to give practical effect to this control gave rise to anxious thought.

Attempts to " Swab " large Numbers of Men.—It is clear that if it is practicable to make a bacteriological examination of swabs taken from the naso-pharynx of each soldier in a barrack or camp, and if all soldiers found to be carriers were segregated and could be cured of their carrier condition, freedom from the disease would follow, as the source of infection in the camp would be removed. The amount of work entailed in carrying out such universal " swabbing " is directly proportional to the number of men dealt with. It can readily be seen that for practical purposes it would be impossible to extend this method to the whole army.

However, in certain instances where a regiment had a succession of cases, the whole of the men were examined by naso-pharyngeal swabbing and, on the segregation of all those found to be carriers, clinical cases of the disease ceased in the regiment so dealt with, and while the bulk of the carriers detected soon ceased to harbour the meningococcus in their naso-pharynges, the examination discovered the existence of a few chronic carriers who retained the carrier condition for a long period, in some cases for months. It is probable that the persistence of the infection in the regiments concerned was due to the presence of these chronic carriers.

These attempts to examine each man in a regiment clearly showed how impracticable it was to deal in such fashion with a camp of even a few thousand men.

The following is a brief account of instances in which the attempt was made.

In 1916, when large drafts were urgently required for overseas service from Chatham, and it was known that certain men in these drafts had developed cerebro-spinal fever in France, an attempt was made by Captain R. R. Armstrong to eliminate "carriers" from that portion of the garrison principally concerned. Between 28th March and 2nd May, 1916, he swabbed 8,456 men. The magnitude of this task and the rapidity with which it was carried out precluded serological tests in the first instance, but from the number of men examined 410 were segregated as having micro-organisms in their naso-pharynges closely resembling the meningococcus. Captain Armstrong was unable to complete the work as he himself had to leave for overseas service. The work was taken over on 2nd May and finished by Major W. J. Tulloch, of the central laboratory. He found that 86 of these men had become free from suspicious micro-organisms and that such organisms were still present in the remaining 324 cases. These were further examined serologically and 173 were found to be carriers of the meningococcus. On 12th June there were still 30 carriers under treatment.

There were two cases of cerebro-spinal fever in the 3/1st Herts Yeomanry in November 1915, when the unit was stationed at Reed Hall Camp, Colchester. It moved to the Cavalry Barracks, Colchester, where two further cases occurred, one in January and one in February 1916. In the spring the unit proceeded to Crowborough and then to Uckfield, and on 10th April one yeoman who had been isolated for measles fell sick with cerebro-spinal fever at Crowborough and on the same date another case occurred at Uckfield. As the unit was only about 360 strong, and a new draft of some 200 recruits was shortly expected at Uckfield, it was decided to make a complete bacteriological examination of the men in order to eliminate any possible carriers. This was done partly by the bacteriologist of the Brighton laboratory, but the bulk of the work was carried out by the staff of the central laboratory, the motor laboratory being used for the purpose. Twenty-five carriers were detected; of these six were chronic carriers who resisted treatment and were still "positive" on 5th August.

Between 15th March and 6th April, 1917, twelve cases of cerebro-spinal fever occurred in the 31st Training Reserve Battalion stationed in the Dover Garrison, and one other case, that of a man attached to the battalion for duty. One case was that of a recruit with two weeks' service, while of the remaining patients, four had three weeks', six had four weeks', and one had six weeks' service. The attached man had had eight weeks' service.

The battalion was composed of 25 officers and over 2,000 men. There were but few old soldiers, the great bulk being young recruits of whom large numbers had joined the battalion between 5th and 13th March. The unit was isolated from the rest of the garrison on 30th March. Spraying of the whole battalion was commenced on 4th April and only one case of cerebro-spinal fever occurred after that date. Measles had been prevalent in the battalion and cases of this disease ceased almost entirely within about three weeks of the commencement of the spraying. A sample of the unit had been systematically swabbed by the local laboratory with results not in accordance with those obtained after the use of the steam spray in other places.

Colonel Reece visited Dover on 16th May. The general sanitation of the camp was good, but there was overcrowding in certain huts. The ventilation of the huts was improved and marquees pitched to enable the men to be spaced out; new blankets were issued and old blankets disinfected. It was thought desirable to investigate the matter, and Major Hine and Major Bell, of the central laboratory, proceeded to Dover with the travelling laboratory, and systematic swabbing of the entire unit was commenced on 23rd May. The examination was completed by 15th June, and out of 2,063 men examined 165 carriers were detected. On 18th July, 2 officers, 4 N.C.Os. and 35 men still remained carriers.

Cerebro-spinal Fever on Outgoing Transports.—It will suffice to recall one instance in which the central laboratory staff reinforced a local laboratory staff and dealt with an emergency on outgoing transports, and the following account is an illustration of what can be accomplished by determination and energy :—

On 31st December, 1916, a case of cerebro-spinal fever occurred on a ship that had on board 200 passengers and 1,400 troops. This ship was in Plymouth Sound together with several others waiting to sail under escort. On the notification of the case and intimation of the fact concerning its occurrence on a transport, Major Hine went on 3rd January by train and Mr. Laws, bacteriologist, travelled with the mobile bacteriological laboratory to Devonport, arriving on the following day. A second case occurred on 3rd January on another transport at Plymouth that had on board about 250 officers and men. On the occurrence of the first case, Colonel J. B. Gibbons, the embarking medical officer, had segregated on shore 19 men as intimate contacts of the case and had removed about 290 other men from the troop-deck on which the case had occurred. The case from the second transport had slept alone on a hatchway and had been in the ship's hospital three days previous to being removed on 3rd January from the ship. In this instance, Colonel Gibbons had isolated 13 men, chiefly hospital attendants and messmates, as intimate contacts. The contacts had been swabbed by the staff of the Plymouth laboratory but the results were not known on 4th January.

The ships were under orders to sail and, although the exact date and hour of sailing was not known, the men had orders to embark at 2 p.m. on 5th January, and in fact the ships sailed at 5 p.m. on that day. The time available for bacteriological examination was very short. It was obviously impossible to swab the men on the ships and it was decided to concentrate on the men who had been landed and segregated.

Major Hine furnished a report of his examination by 1 p.m. on 5th January, but he pointed out that, owing to lack of time, his result could only be regarded as likely to detect the men most heavily affected. The examination of the plates showed that, of the 13 men from the second ship, 7 were apparently positive, and of the 19 men from the first ship, 6 were positive, whereas of the 291 other men from this ship there were only 14 positive. This result indicated that the selection of the intimate contacts had been made with good judgment and success. The 27 positives were retained and the remaining 296 men sailed with the ship, and no untoward event happened.

This investigation brought to notice the fact that outgoing transports were not supplied with anti-meningococcic serum, syringes, or lumbar puncture needles ; and this omission was remedied.

Housing of Troops as a Factor in the Prevalence of Cerebro-spinal Fever.

When considering the possibilities of spread of infection among troops some general idea can be obtained by comparing their housing conditions with those of the civil population. The average number of civilians per house in England and Wales is roughly five persons, and when infectious disease occurs in a house, the liability of its spread is limited to the number of susceptible persons in the household. The number

of soldiers in a barrack-room or hut usually far exceeds five, and if an arbitrary figure, say thirty, is taken, it will be seen that the liability of the soldier to contract the infection is at least six times as great as that of the civilian. But this numerical basis is not the sole factor, inasmuch as the five civilians, while they might share a room during the day, would be separated at night and sleep in two or three bedrooms. In ordinary circumstances the bedrooms are occupied for an uninterrupted and longer period than the day room. The soldier, however, has only one room, which serves as his day room and bedroom. During the night the air in a room is more or less stationary, in part due to the occupiers not moving about, and the humidity of the atmosphere increases.

The ordinary person dislikes draughts and the soldier is no exception to this rule. Notwithstanding advice, instruction, and close supervision by regimental officers, the soldier almost invariably has a tendency to block or obstruct the ventilation. To realize how contaminated the atmosphere may become one has only to enter an occupied barrack-room or hut in the middle of the night or in the early hours of the morning.

The hygienist who knows that certain barrack-rooms or huts have sufficient space to accommodate the given number of men requiring to be housed may consider that the matter is disposed of, unless he realizes the importance from the military point of view of keeping units, companies, and platoons together under the immediate supervision of their own officers and N.C.Os. The tendency in the army is to collect the men of a unit together and to concentrate them in certain rooms or huts rather than disperse them and mix them with men of other units. This is a serious difficulty in spacing men out, and it constituted one of the problems which had to be reckoned with and considered carefully from the point of view of the officers in executive command.

Barracks.—The barracks, in regard to their suitability for housing soldiers, vary within very wide hygienic limits. While the modern barracks, erected immediately prior to the war, leave little to be desired, the old barracks, dating back fifty years or more, do not comply fully with modern requirements, notwithstanding structural alterations in recent years. The mobilization for war necessitated the use to their fullest extent of all available barracks. A barrack-room which approximates to a square, and affords the 600 or the 400 cub. ft. of space for each inmate and 60 or 40 superficial feet per bed, will lack, when the beds are arranged with the head of each bedstead

against the wall, the most essential measurement, namely, space between beds. In such circumstances, when spaces occupied by fireplaces, doors, etc., are taken into account and the beds are arranged round the available wall space, they are practically touching one another. Also in these square barrack-rooms it frequently happens that there are windows only in one wall, and for cross-ventilation the room depends to a large extent on the fireplace and the door. In such instances the attempt was made to secure the required distance between " heads " by drawing alternate beds several feet from the wall and by placing certain beds in the central floor space at night.

Huts.—Although many kinds of army huts were built and the designs varied within wide limits, there were two types that came to be regarded as the standard patterns. One type measured 60 ft. by 20 ft. and the other 60 ft. by 15 ft. Such huts on the standard of 600 cub. ft. and 60 super. ft. per man accommodated 20 and 15 men respectively, and on the 400 cub. ft. and 40 super. ft. mobilization basis they housed 30 and 22 men respectively. The available wall space per bed is influenced by the position of the stove, whether this is situated in the centre of the hut or at the side. When in the latter position it occupies space that might otherwise have accommodated a bed. From the point of view of wall space per bed, provided the cubic capacity and superficial area are adhered to, there is advantage in the 60 ft. by 15 ft. hut, as this, on the long sides alone, and without taking the short sides into consideration, allows, even when the fireplace is placed on one of the long sides, 7½ lin. ft. and 5 lin. ft. per bed on the 600 cub. ft. and 400 cub. ft. per bed basis respectively; whereas the 60 ft. by 20 ft. hut gives only 6 ft. and 4 ft. per bed respectively, and this without allowing for the fireplace.

The position of the stove in a hut is of importance from the dual point of view of the available amount of space warmed and the facilities afforded for spread of droplet infection. When placed centrally the men sit round the stove in a circle, but when it is against the wall the warmed space is limited to a semicircle.

Some of the huts erected were of very large size, a single hut being built to accommodate 400 men. When infectious disease breaks out in such a hut, administrative procedure in dealing with the occurrence is seriously handicapped owing to the large number of "room contacts." On one occasion when cerebro-spinal fever occurred in one such hutment, 352 men were swabbed and 14 carriers detected. It must be borne in

mind that under ordinary conditions a bacteriologist can only deal with about 100 men per day, and on each succeeding day this number becomes less, as a certain number of the plates have to be sub-cultured. Also the capacity of the incubators is necessarily limited, and although the number of plates dealt with varies with the size and number of the incubators, it is manifest that for practical purposes the number of incubators in a laboratory must be restricted. To meet this difficulty the bacteriologists not infrequently dealt with two swabs, and, under great pressure, with four swabs on one plate.

Billets.—Although billets varied considerably, those in private houses could be regarded as satisfactory on the whole; at any rate, the soldiers and civilians were housed under like conditions. In many instances, not only in the poorer class of dwellings, but also in the better-class residences, the householders devoted much thought and care to the comfort of the troops. The disadvantage of this class of billet was that when a bedroom occupied by two soldiers contained only one bed, and that a double bed, the two soldiers slept in it. It was of little avail to point out that one of them should sleep on the floor wrapt in army blankets. This type of billet cost more per head than unfurnished houses, public halls, disused factories, etc. In the latter type men of a unit could be grouped together, and central cooking and feeding rooms could be instituted. Therefore, not only on the score of expense but also for purposes of supervision, such places when available were used in preference to billeting soldiers on the civil population. While some of this type of billet compared closely with the ordinary barrack accommodation, except that often latrines and ablution arrangements were deficient, there were others in which the reverse was the case, and in which ventilation was seriously defective. Also, from the early days of the war, the windows of billets on the east and south coast overlooking the sea, and of those inland during the period of air raids, were screened at night. In many halls used as billets the window panes were coloured dark blue; the direct rays of the sun were excluded and the interiors were always dark; this had a depressing effect on the spirits of the men. At night, army blankets were in many instances fixed up across the windows, impairing the ventilation when it was most needed. Several limited outbreaks of cerebro-spinal fever occurred among men so housed, and this circumstance had the immediate result of having these halls and factories put into reasonable sanitary condition or led to their ultimate evacuation. Such outbreaks, however,

were not limited to these places; a certain number also occurred in private billets. It must be remembered that in the early days of the war many medical officers had not previously done duty with troops, and these officers had yet to learn that their first and most important duty was to keep their men fit. In the selection of billets and when arranging for the number of men who should be housed in a billet, in some instances either the medical officer of the unit was not consulted or he failed to appreciate the principles of hygiene involved.

Captain Gaskell and other officers engaged in cerebro-spinal work, by drawing attention to defective or overcrowded billets, did much useful work in connection with the evacuation of insanitary billets and in the amelioration of unhygienic conditions.

TABLE I.

This Table provides a Superficial Space of 60 ft. for each Man.

	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
8	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3
9	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3
10	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	4	4
11	1	1	1	2	2	2	2	2	2	3	3	3	3	3	4	4	4	4
12	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	4
13	1	1	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5
14	1	2	2	2	2	3	3	3	3	3	4	4	4	4	5	5	5	5
15	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6
16	2	2	2	2	3	3	3	4	4	4	4	5	5	5	5	6	6	6
17	2	2	2	3	3	3	3	4	4	4	5	5	5	5	6	6	6	7
18	2	2	3	3	3	3	4	4	4	5	5	5	6	6	6	6	7	7
19	2	3	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	7
20	2	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8
21	2	3	3	3	4	4	4	5	5	6	6	6	7	7	7	8	8	8
22	2	3	3	4	4	4	5	5	5	6	6	7	7	7	8	8	8	9
23	3	3	3	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9
24	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10
25	3	3	4	4	5	5	5	6	6	7	7	7	8	8	9	9	10	10

TABLE Ia.

This Table provides a Superficial Space of 40 *ft. for each Man.*

	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
8	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5
9	1	2	2	2	2	2	3	3	3	3	4	4	4	4	4	5	5	5
10	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6
11	2	2	2	3	3	3	3	4	4	4	4	5	5	5	6	6	6	6
12	2	2	3	3	3	3	4	4	4	5	5	5	6	6	6	6	7	7
13	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8
14	2	3	3	3	4	4	4	5	5	5	6	6	7	7	7	8	8	8
15	3	3	3	4	4	4	5	5	6	6	6	7	7	7	8	8	9	9
16	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10
17	3	3	4	4	5	5	5	6	6	7	7	8	8	8	9	9	10	10
18	3	4	4	4	5	5	6	6	7	7	8	8	9	9	9	10	10	11
19	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	11
20	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12
21	4	4	5	5	6	6	7	7	8	8	9	10	10	11	11	12	12	13
22	4	4	5	6	6	7	7	8	8	9	9	10	11	11	12	12	13	13
23	4	5	5	6	6	7	8	8	9	9	10	10	11	12	12	13	13	14
24	4	5	6	6	7	7	8	9	9	10	10	11	12	12	13	13	14	15
25	5	5	6	6	7	8	8	9	10	10	11	11	12	13	13	14	15	15

As an aid to medical officers, Major Fegen drew up a scale in diagrammatic form which showed at once the approximate number of men who could be housed in rooms of various sizes, while securing per head the appropriate amount of floor space and cubic space. A copy of this scale is shown in Tables I and Ia, which provide a rapid means of deciding how many men may occupy any room or hut. The figures along the top and along the left-hand side of the tables represent measurements in feet. The length and breadth of the room being roughly paced out and the number of paces multiplied by three, will give the number of feet in length and breadth. The top figures represent the length and the side figures the breadth. From the position of the measurement of

length on top the vertical column is carried downwards to the point where it intersects the horizontal line from the position of measurement of breadth. The point of intersection shows the number of men which can occupy the room. For example, a room 22 ft. long by 17 ft. broad can accommodate 6 men, so that each man will have 60 sq. ft. superficially, according to Table I, and 9 men, so that each man will have 40 sq. ft. superficially, acccording to Table IA.

Tents.—On the occurrence of an outbreak of infectious disease in barracks it has been the custom in the army to place a certain number of men, or all men of the affected unit, under canvas. The advantage of such procedure is to reduce the number of men who are in close association with one another so that in the event of further cases occurring, the immediate contacts of a case are reduced from the number of men in a barrack-room to the number in a tent, *i.e.*, a smaller number of contacts have to be dealt with. It was found, however, that as regards cerebro-spinal fever there was, on occasion, a high carrier rate among the occupants of individual tents. The question of the number of men that should be accommodated in a regulation bell tent was considered by the army sanitary committee. The measurements of a regulation bell tent are:—diameter 13 ft. 6 in., height (length of pole) 9 ft. 6 in., height of side 2 ft., floor space 143 sq. ft., circumference 42 ft. 4 in., and cubic space 684 cub. ft. The late Brigadier-General F. J. Anderson, R.E., pointed out that a man lying down in such a tent with his feet to the pole would have his mouth on the circumference of a circle of one foot less radius than that of the tent; and that if the occupied floor is spaced as an undecagon and one space left for the doorway of the tent, the remaining ten spaces would allow of a distance of 3 ft. 3 in. between the centres of the heads of ten men equally spaced out. Further, if the floor of the tent is divided as a heptagon, and one space is left for the doorway, the distance between centres of heads would be 5 ft. The commands were informed that "during the period of the present war the proportions of men to be accommodated in circular single lined tents should be reduced to eight mounted men or ten dismounted men per tent, and that in the event of a threatened epidemic of infectious disease, troops should be at once spaced out to such an extent as will admit of not more than six men (mounted or dismounted) occupying a tent."

Attempts were made when dealing with battalions of young soldiers to limit the number of men to six per tent, and although

this attempt met with considerable success, still it was not always possible to arrange owing to a sufficient number of tents not being available.

Observations relating to Administrative Control, Epidemiological and Ætiological Factors of Cerebro-spinal Fever.

Effect of Spray Treatment.—There can be no doubt that the steam spray treatment reduced the carrier rate among troops submitted to this process. As instances of this, when cases of cerebro-spinal fever occurred in the 6th London Rifle Brigade at Blackdown Camp, Captain Lundie, the bacteriologist in charge of the Aldershot Laboratory, found that the carrier rate in the unit was 20 per cent. The entire battalion, 1,000 men, was passed seven times through the spraying chamber between 5th and 19th March 1918, after which the carrier rate fell to 4 per cent. At Bordon Camp the carrier rate among the R.F.A. was found to be 22 per cent., and between 9th and 15th March 1918, 1,900 men were passed seven times through the chamber of the mobile steam spraying apparatus and the carrier rate fell to 12 per cent. Somewhat similar results were obtained at other camps and the matter was specially investigated by Captain Glover, the bacteriologist in charge of the London District Cerebro-spinal Fever Laboratory, who made regular observations extending over a long period of time of the carrier rate at the Guards' Depôt at Caterham, and furnished several valuable reports on this and allied subjects.

It was found that not only did the steam spray treatment lower the carrier rate, but that after troops were submitted to the treatment further clinical cases of the disease did not occur, and this notwithstanding that the carrier rate might not be very much reduced. This absence of clinical cases could not be attributed altogether to the lessening of the number of carriers; it may have resulted in part from a reduction in the number of meningococci in the naso-pharynges of those who still remained carriers, and this reduction may have limited the ability of the carriers to disseminate infection, or again the infective power of the meningococcus may have been reduced. That the steam spray treatment minus the disinfectant produced no effect on the carrier condition was demonstrated by the occurrence referred to on p.245. It is possible that the disinfectant operates in some manner directly as such and also indirectly by accelerating the natural processes by which carrier condition is cleared up by increasing the local circulation of lymph.

Incubation Period of Cerebro-spinal Fever.—It is by no means easy to determine the length of the incubation period of the disease, owing to the difficulty of ascertaining the actual or probable date of exposure to possible infection. It is not possible to decide whether carriers found among contacts of a clinical case were infected by the case or whether the patient received infection from a carrier. Further, it is not known how long a person may be a carrier before developing meningeal symptoms; it is certain that the great bulk of carriers never do. The following cases are of interest in this connection. A soldier was attacked by cerebro-spinal fever and admitted to hospital, where his mother visited him. Four days after her visit she was taken ill with cerebro-spinal fever, and admitted the following day to the local isolation hospital, where she died three days after admission. She lived in a remote rural district where no cases of cerebro-spinal fever had been known to occur. If the woman acquired the infection from her son the incubation period in her case would be four days.

It is more difficult to define the exact date of exposure to infection when dealing with cases in the military population, where the men are closely associated, than it is in regard to cases in the civil population. The following cases reported by Captain E. H. Shaw* are given as possible instances for estimating the length of the incubation period. Two soldiers, "A" and "B," belonging to different regiments and separately housed, were, by a misunderstanding, removed to hospital together in an ambulance on 11th February 1917. "A" was suffering from a distinct attack of cerebro-spinal fever, "B" from acute bronchitis, and the latter showed no signs of cerebro-spinal fever. "B" died of a fulminating attack of cerebro-spinal fever two days later. Possibly the bronchitis from which "B" suffered may have rendered him peculiarly liable to infection, and unless he was actually suffering from cerebro-spinal fever, of which bronchitis was a symptom, the circumstances indicate that the incubation period may be as short as two days.

Again, "C" found "D" unconscious in a latrine and helped him to bed and looked after him. "D" proved to be an acute case of cerebro-spinal fever, and five days later "C" developed symptoms of the disease.

Infectivity or Contagiousness of Cerebro-spinal Fever.—It has been stated that cerebro-spinal fever has a low degree of infectivity. This statement is probably correct if it is limited

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* Report from the Cerebro-spinal Fever Laboratory, Central Military Hospital, Aylesbury, 1917.

to the cases that develop clinical symptoms indicative of involvement of the cerebro-spinal system, but incorrect if persons who harbour the causative organism are regarded as persons suffering from the infection. Inasmuch as these latter persons seldom or never suffer discomfort and may be, and generally are, unaware of their condition, the infection may become widespread in a community, and its presence only realised when some person suffers an attack which is clinically recognized as cerebro-spinal fever. The many instances of multiple cases of the clinical disease that have occurred in families show that at times the infection may operate with great virulence under favourable conditions.* On the other hand, spread of infection in hospitals has not been a marked feature of the disease. This may be due to the care taken to ventilate hospital wards and to the fact that in hospitals there is as a rule ample space between beds. Nevertheless, from time to time nurses engaged in attendance on cases of cerebro-spinal fever suffered clinical attacks of the disease. There are records of fifty such instances, twenty of them with fatal results, during the years 1915-18, among nurses in attendance on military cases. Medical officers in attendance on the sick developed the illness in four instances, and three of them died. Also bacteriologists engaged in cerebro-spinal fever work did not escape, and at least two died of the disease. Taking the number of nurses and medical officers who were at one time or another brought into close relations with the clinical cases of the disease, the number attacked cannot be considered high. Nevertheless, the fact that such persons were liable to attack was recognized, and those in attendance on the sick were recommended to wear damp gauze or lint masks.

Infection traced to a particular Carrier.—It has been stated by certain observers that it is not possible to trace the infection of cerebro-spinal fever to a definite carrier, but although conclusive evidence is often impossible, nevertheless the investigation has on several occasions resulted in establishing evidence of infection which is indisputable. Reports on a series of such cases have been published by Colonel Martin Flack and Captain Glover, and cases are recorded by other observers. The following abstract from a report by Captain W. Allan† presents points of interest :—

* See Report of the Medical Officer of the Local Government Board 1917–1918, pp. 55–56, and Report of the Medical Department of the Local Government Board 1918–1919, pp. 48–52.

† Bacteriological Report 1917–1918, Extended Area (London District) Eastern Command.

Case of W. This patient was in the next bed to Sergeant C., a carrier (Type III). When seen as a suspect on 3rd March 1918 he "had no pyrexia, no headache, no neck stiffness, his cerebration was good and the malaise comparatively slight. He was lumbar-punctured and the fluid was clear and sterile . . . his naso-pharynx also yielded no meningococcus . . . . he went on well and without pyrexia until 7th March, when he had a very sudden onset of definite cerebro-spinal fever, severe headache and vomiting, a temperature of 104°, with marked neck stiffness and Kernig. He was again seen as a suspect and lumbar-punctured on the 7th March. This time the fluid was turbid and yielded a growth of Type III meningococcus, the same type as that carried by Sergeant C., who, four days previously, had been in the next bed. Moreover, Type III was at that time an unusual type at Hounslow ; a sample of 105 men taken there on 13th March, which showed five carriers of other types, did not yield a single Type III. The fact that Sergeant C. was restless, calling out, shouting, etc., probably increased his spraying power, as infection in hospital conditions is distinctly rare. The incubation period appears to have been just four days, and more conclusive proof of infection by a particular carrier is seldom furnished."

Carriers developing Cerebro-spinal Fever.—Several instances occurred in which men who had been swabbed with negative result subsequently developed clinical symptoms of cerebro-spinal fever. In considering how and when infection may have taken place, it was not possible to exclude the possibility of infection subsequent to the swabbing ; also the meningococcus may have been present in the naso-pharynx when swabbing took place and it may have been " missed " by the bacteriologist. But such cases gave rise to the suspicion on the part of certain observers that when once the meningococcus became established in the naso-pharynx the carrier was safe from a clinical attack of cerebro-spinal fever. This theory is certainly incorrect, though it received some support in view of the number of known carriers who never showed clinical symptoms of the disease. Captain Lundie in his 1916-17 report states, " It is a remarkable fact that of all the numerous carriers isolated at the School of Army Sanitation, Aldershot, not one ever developed cerebro-spinal fever ; " but he adds, " Only one of all our carriers, who was isolated in another place, developed the disease, after the lapse of a week."

There have been, however, a good many cases in which known carriers developed clinical symptoms and in which the meningococcus was recovered from the cerebro-spinal fluid. For instance, a soldier was attacked by cerebro-spinal fever and admitted to the Lucknow Casualty Clearing Station on 25th October, 1917. A contact of this patient was swabbed on 25th October, with positive result, and on 3rd November he was admitted as a clinical case of cerebro-spinal fever to the Lucknow Casualty Clearing Station.

A soldier who had helped to remove a case of cerebro-spinal fever was swabbed as a contact on 26th February, 1917, and

found to be positive. He developed clinical symptoms of the disease on 5th March.

A carrier, who was apparently in good health till the sudden onset of his illness, developed the disease ten days after he had been proved to be a carrier.

When attention was specially directed to the matter it was not at all uncommon to find that carriers developed minor meningeal symptoms while in isolation. Such symptoms lasted for only brief periods and amounted to little more than a headache accompanied by a slight rise of temperature and perhaps vomiting. Major Vining, who specially noted such cases, reported that "amongst the carriers at Killingbeck, seven had short bouts of headache without rise of temperature or other symptoms; eight had temperatures and headaches for one to four days but were otherwise perfectly well; three had headache intermittently over several weeks and two had backache and headache with no other symptoms. None of these men were at all ill and mentally were quite clear." Such instances raise the question whether the development of graver symptoms was nullified by the disinfectant treatment to which these carriers were being subjected. If indeed such were the case, this modification was not always operative, as the following case indicates:—

In July 1918, a soldier at Dreghorn Camp was swabbed as a contact of a case, found to be positive, and isolated. Five days later he developed clinical symptoms of the disease and the meningococcus was found in his cerebro-spinal fluid. Prior to the onset of the disease he had, as a contact, been passed on one occasion, two days before his clinical attack, through the Levick spray chamber and he was said to have practised daily nasal insufflation with potassium permanganate solution from the time that his carrier condition was recognized.

How long a person after he has acquired infection of the nasopharynx by the meningococcus may suffer a clinical attack of the disease cannot be stated. Colonel Flack has recorded a case in which a soldier who had been isolated as a carrier for six weeks developed the disease. It is, however, quite possible that this time falls short of the maximum period.

The Influence of Travelling in determining an Attack.—It was noticed that a considerable number of cases occurred shortly after travelling, particularly after long railway journeys, men proceeding on leave developing the disease within a few days of arrival at their homes, or when transferred from one camp to another. The close association of a number of men in

overcrowded railway carriages doubtless afforded time and opportunity for a carrier to distribute infection. With this were associated fatigue, exposure to variable temperature, and loss of regular meals, all factors lowering the power of the body to resist infection. There were also many instances in which a man who had left a camp in apparently good health was attacked on the journey, and on occasions men were removed from trains in an unconscious condition.

Relapses.—Some patients who had suffered a severe attack of the disease and recovered, and who had not been discharged from the army as medically unfit, suffered a relapse or a recrudescence of the disease on return to military duty. The opinion was gradually formed that such men were unfitted for the strenuous work of the soldier, and that it was probably the best course to discharge from the army patients who had recovered from a severe attack of cerebro-spinal fever.

Lumbar Puncture under a General Anæsthetic.—The occurrence of one or two deaths during the administration of a general anæsthetic for the operation of lumbar puncture led to careful consideration of the matter. The consensus of opinion was that the best results were obtained under a general anæsthetic. When lumbar puncture is performed several days in succession on a patient without an anæsthetic, he comes to dread the operation and, apart from the fact that it becomes a real terror to him, there is the difficulty in keeping him still or from flinching when the needle is inserted. Further, the attempt to lumbar puncture, without a general anæsthetic, a violent patient suffering from cerebral meningitis and to restrain his movements by force, has been known to be followed by the death of the patient. From a clinical point of view it was considered that a larger amount of cerebro-spinal fluid could be withdrawn under a general anæsthetic than was otherwise the case, and that the resulting sleep was of great advantage to the patient. It was not thought advisable to lay down any hard and fast rule on the matter in the official memorandum but to leave the decision to the medical attendant, while stating that experience had shown the best results are attained under a general anæsthetic.

Protective Inoculation.—Protective inoculation was at one time attempted. At Bovington Camp twenty-two cases of the disease occurred among troops from which drafts were required for overseas, and 3,622 men out of 5,528 were fully inoculated. In the next six weeks five fresh cases occurred, four of them being in inoculated men. While this result cannot be regarded

as in any way conclusive, the experiment brought into prominence the undesirability of attempting to protect troops against the disease in this way while they were undergoing intensive military training, during which they were inoculated against enteric fever and vaccinated against smallpox. A third inoculation against a possible infection could not be undertaken without undue interference with military training. Further, it was known that there was a considerable number of carriers among the troops, and there was the possibility that the injection of a dose of meningococcus vaccine sufficient to confer, for a considerable time, a reasonable degree of immunity, might temporarily depress the resisting power of a carrier and render him liable to a clinical attack of the disease. It was decided, therefore, not to attempt any general protective inoculation against cerebro-spinal fever.

Sterilization of Drinking Vessels.—This measure of prevention had been recommended in many barracks, hutments and camps, where cases of cerebro-spinal fever had occurred, and it formed the subject of an Army Council Instruction* to the effect that every drinking vessel should immediately after use be well washed in hot water and dipped in boiling water in such a manner that the upper 2 in. inside and out become immersed.

The Coal Ration as a Factor influencing the Spread of Infection of Cerebro-spinal Fever.—There was not a superabundance of coal and the quantity issued to troops was based generally on the number of men present in barrack or camp, and not on the number of apartments to be warmed. Owing to the fact that some of the available accommodation could not be warmed, it was found difficult, in times of inclement weather, to space men out so that there should be a minimum number of men in each barrack-room or hut. The effect was that men objected to living in unwarmed rooms and huts and tended to collect in quarters where there was a fire.

The Convalescent Hospital at Hitchin.—It was early recognized that it was desirable to have a convalescent hospital to which patients who had recovered from a severe attack of cerebro-spinal fever could be sent before being drafted to special hospitals for treatment of paralysis and other sequelæ of the disease. These special hospitals hesitated to take patients direct from an isolation hospital. A suitable building was found in the German Hospital at Hitchin, which was taken over on 28th March, 1915, and opened about a month later as a convalescent hospital. The hospital was well

* No. 397 of 1918.

designed and built, standing on high ground, and had 9 acres of land, partly pleasure and partly kitchen garden. It had accommodation for fifty-seven patients and staff. A senior non-commissioned officer was put in charge and a local medical practitioner visited the hospital daily to give the necessary medical attention to the patients. At one time, under pressure, carriers of the meningococcus were also sent to this hospital, but it was soon found that it was not possible to prevent the spread of the carrier condition to other residents and the practice was discontinued. The hospital was in the Eastern Command, but patients from the other commands were sent to it to be drafted to suitable special hospitals or kept under treatment pending return to their regiments or discharge from the army as medically unfit. Elaborate care was taken to prevent carriers being admitted, and before patients were sent to the hospital two negative swabs were required. At one time all the inmates were swabbed by the staff of the Central Laboratory at intervals of about a fortnight, to ascertain whether any were carriers. Later this duty was undertaken by the military bacteriologist of the London District Laboratory, and any carriers detected were transferred to the carrier centre at Saunderton for treatment. It was therefore possible to transfer patients from this convalescent hospital to the special hospitals with some assurance that there would be no spread of infection.

"*Carrier*" *Centres*.—The undesirability of keeping carriers in camps and the importance of placing them under expert treatment were recognized, and command carrier centres were established to which carriers who did not become free of this condition or yield readily to treatment in a short space of time could be sent for treatment and be under the care of the bacteriologist. These centres were either specially selected in segregated places situated in camps, or certain buildings were taken over for the purpose; for instance, the Blean and the Saunderton centres in the Eastern Command were old workhouses. In the event of one centre being overcrowded attempts were made to transfer a certain number of the carriers to another centre. Difficulty was often experienced in this transference, as the railway companies objected to conveying carriers owing to the inconvenience associated with the disinfection of the compartments that had been occupied by the carriers in transit, and it was not always possible to send the carriers by motor transport. A monthly nominal roll of the carriers at each centre was sent to the War Office. This return

showed, in addition to the soldier's name, the date on which he was admitted, the dates on which he was swabbed and the result of the swabbing.

It was found generally that the carrier condition cleared up more speedily at the centres situated on the eastern side of England than at other centres. Further, the transference of carriers from one centre to another seemed to have a good effect, and the carrier condition which had lasted for several weeks rapidly cleared up with the change of residence. Certain carriers who had given negative results and had been returned to their regiments were found on examination at a later stage to be harbouring the meningococcus in their naso-pharynges, but in such cases it was not possible to say whether there was a recrudescence of the carrier condition or whether the man had become reinfected on his return to camp life. It is, of course, possible that certain men are more prone to acquire the carrier condition than others, and may become infected readily, or that the bacteriologist may not always find evidence of the presence of the meningococcus, especially in cases of very slight infection.

The length of time that carriers were under treatment at these centres varied within very wide limits, and much time and attention were given to the chronic cases.

During many months at Netley, Major Embleton carried out very exact observations on the carriers under his charge, and spared no effort to arrive at a satisfactory solution of the difficulties encountered; yet in spite of persistent efforts several of the patients remained chronic carriers for months.

It appeared that when one method of treatment failed a change in treatment was frequently successful, but there were cases which resisted treatment for months and, notwithstanding assiduous care and attention on the part of expert bacteriologists, showed no improvement in their condition. Such cases were the despair of the bacteriologist, who, in certain instances, came to the conclusion that treatment was of no avail and that the carrier, if he did not free himself of his condition by natural means, could not be assisted to do so by medical treatment, which might even aggravate the condition. The result can only be regarded as unsatisfactory.

Transports.—With the development of submarine warfare all port-holes of ships were closed and hatches battened down and the ships made as air-tight as possible while in the danger zone. This led to stagnation of air for varying periods, in some cases as long as a week, and to consequent fouling of the air breathed. There were no special arrangements for pumping

fresh air into the ships to counteract these conditions brought about by the precautions necessary to safeguard the lives of those on board against enemy attack.

The military exigencies required the troops to be carried in transports in excess of the regulation number and the conditions existing on board transports were such as to favour in the highest degree the spread of infections that are acquired through the respiratory passages. Under such conditions certain men fell sick during the voyage, but others only developed disease after they had been landed from transports, and every man so landed might be a possible factor in the spread of disease; his capacity to do this could not be determined by ordinary medical inspection on his arrival.

At ports of embarkation or in camps in which troops were concentrated before embarkation, and in which cases of cerebro-spinal fever or other diseases, spread through infection by the naso-pharyngeal tract, were likely to occur, the ideal aimed at was to establish permanent steam spray disinfecting huts and as far as possible to submit all troops to spray treatment for six or seven days before embarkation. This was done in New Zealand with excellent results. Steam spray disinfecting plant should also be available at each centre to which troops are sent from transports, so that troops arriving in transports known to be infected should receive a week's steam spray treatment immediately on arrival.

In the year 1917 there were landed from transports in the United Kingdom 51 cases suffering from cerebro-spinal fever (from Australia 38, New Zealand 6, Canada 3, United States 4), and 179 cases occurred among overseas troops in the United Kingdom (from Australia 110, New Zealand 26, Canada 34, South Africa 5, West Indies 1, United States 3). From 1st January to 18th September, 1918, 29 cases were landed (from Australia 3, New Zealand 2, Canada 7, United States 17), and 134 cases occurred among overseas troops in Great Britain (from Australia 20, New Zealand 22, Canada 69, South Africa 3, United States 20).

At one time it was suspected that the occurrences of cerebro-spinal fever among troops on Salisbury Plain were due to the importation of the infection of the disease by Australian troops.

On certain occasions when cerebro-spinal fever broke out on transports the troops were landed for some days at Colombo, South Africa, and Sierra Leone.

The outbreaks of infectious disease on board transports in 1918 led to a thorough inquiry by a committee. The shortage

of vessels available for transport of troops and the difficulty of effecting structural alterations on ships prevented the full adoption of the measures recommended by the committee and the Army Medical Advisory Board, especially in regard to the space allowed per head to the troops on transports and the mechanical ventilation of these ships on the propulsion system; but minor improvements were effected. The experience gained in these matters and the suggestions for further improvement in the sanitary and medical arrangements of transports are recorded in the Chapter on the Hygiene of Transports.*

Fatality in Hospitals.—A study of the circumstances of fatal cases, according to diagrams prepared by Major R. Bruce Low, showing for the two years, July 1916 to June 1917 and July 1917 to June 1918, the number of cases received into the several hospitals and the proportion of these cases that proved fatal, brought into prominence the fact that in the main the fatality was less in those hospitals which received the greatest number of cases.

The explanation of these differences is possibly that in hospitals to which many cases were admitted the general character of the disease was known, the nature of the illness promptly recognized, and the patient received early and appropriate treatment and efficient nursing based on a knowledge of the malady, whereas the opposite appertained in hospitals to which a single case or very few cases were admitted.

Statistics.

The Extent of Cerebro-spinal Fever Prevalence and Fatality among Troops at Home.—Notification of cerebro-spinal fever was made compulsory in England and Wales on 1st September, 1912, and from that date it is possible to estimate with some degree of exactitude its distribution in time and place among the civil population. Accounts of its prevalence in the civil population with certain references to its relation to the military population have been published in the Annual Reports of the Local Government Board. The circumstances in which the disease first appeared among British troops towards the end of 1914 formed the subject of an article in the *Journal of the Royal Army Medical Corps* in 1915.

The following table shows the number of cases of cerebro-spinal fever from the first known case in 1914 to the end of the year 1918, together with the number of deaths, the percentage of the total cases and the percentage of deaths to cases that occurred among troops in the English, Scottish, and Irish Commands, and in the Channel Islands.

* See Vol. I, Hygiene of the War, Chapter XVI.

TABLE II.

Cerebro-spinal Fever in the Army, 1914–1918.

Table showing the Cases, Deaths and Death-rates in Home Commands.

Command.	1914–1915.				1916.				1917.			
	No. of Cases.	No. of Deaths.	Percentage of		No. of Cases.	No. of Deaths.	Percentage of		No. of Cases.	No. of Deaths.	Percentage of	
			Total Cases.	Deaths to Cases.			Total Cases.	Deaths to Cases.			Total Cases.	Deaths to Cases.
Aldershot	236	77	19·0	32·6	111	57	11·5	51·4	99	42	7·4	42·4
Central Force	85	49	6·8	57·6	—	—	—	—	—	—	—	—
Eastern	291	150	23·4	51·5	327	120	33·8	36·7	339	147	25·5	43·4
Northern	61	37	4·9	60·7	89	43	9·2	48·3	284	124	21·1	43·7
Southern	309	153	24·8	49·5	287	142	29·7	49·5	406	172	30·5	42·4
Western	46	30	3·7	65·2	35	24	3·6	68·6	94	46	7·0	48·9
London	85	46	6·8	54·1	64	17	6·6	26·6	64	37	4·8	57·8
Irish	63	34	5·0	53·9	29	13	3·0	44·8	15	6	1·1	40·0
Scottish	68	40	5·5	58·8	24	13	2·5	54·2	34	18	2·5	52·9
Channel Islands	1	1	0·1	100·0	1	1	0·1	100·0	2	1	0·1	50·0
Total	1,245	617	100·0	49·6	967	430	100·0	44·5	1,337	593	100·0	44·4

TABLE II.—*cont.*

Cerebro-spinal Fever in the Army, 1914-1918.

Table showing the Cases, Deaths and Death-rates in Home Commands.

Command.	1918.				1914–15 to 1918.			
	No. of Cases.	No. of Deaths.	Percentage of Total Cases.	Percentage of Deaths to Cases.	No. of Cases.	No. of Deaths.	Percentage of Total Cases.	Percentage of Deaths to Cases.
Aldershot	115	34	16·7	29·6	561	210	13·3	37·4
Central Force	—	—	—	—	85	49	2·0	57·6
Eastern	163	64	23·7	39·3	1,120	481	26·4	42·9
Northern	132	62	19·2	47·0	566	266	13·4	47·0
Southern	143	61	20·7	42·7	1,145	528	27·0	46·1
Western	29	15	4·2	51·7	204	115	4·8	56·4
London	21	4	3·0	19·0	234	104	5·5	44·4
Irish	45	28	6·5	62·2	152	81	3·6	53·3
Scottish	39	19	5·7	48·7	165	90	3·9	54·5
Channel Islands	2	1	0·3	50·0	6	4	0·1	66·7
Total	689	288	100·0	41·8	4,238	1,928	100·0	45·5

In considering these figures it must be borne in mind that the strength of the several commands varied within wide limits and that probably at the end of 1914 and the beginning of 1915 Aldershot may have had a relatively larger population when compared with the other commands than it had at a later date. It was possible later on to estimate the numerical distribution of troops in the several commands, and although the numbers in each command varied from time to time with the movements of troops, the approximate numerical value of the commands was roughly: Eastern 30, Northern 20, Southern 18, Western 11, Scottish 6, Aldershot 5, Irish 5, London 4, and Channel Isles less than 1.

Seasonal Prevalence.—The period of maximum seasonal prevalence of the disease was in the early part of the year, and the greatest number of cases recorded in any one week in 1915 was in the first week in March, and in the years 1916 and 1917 in the fourth week in March.

In the three years 1915–17 the rise and fall of the curve were steep although the fall was less abrupt, and in each year there was a preliminary rise in December. In 1918 the seasonal rise in the early months of the year reached its summit in the second week in February and was less acute and the peak of the curve was less marked than in the previous years. The greatest number of cases in any one week in the year was notified, however, in the second week in July. This corresponded with the epidemic period of influenza.

Persons exposed to the weather conditions in Great Britain during the early months of the year are apt to suffer from respiratory troubles at a time when opportunity for spread of infections acquired through the naso-pharynx is at its height. The circumstances under which the troops lived favoured dissemination of such infections. The men were undergoing intensive training which could not be postponed during adverse weather conditions, their clothes were frequently wet, and opportunities and facilities for drying them were few. The result was that the men hung up their wet clothes to dry in their huts and barrack rooms, causing undue moisture of the atmosphere. They had no inducement to remain in the open air; on the contrary, their inclination was to get under cover in their huts and barracks where they huddled round the stoves for warmth and for the purpose of drying their clothes, and, notwithstanding the vigilance of their officers, windows were shut where possible, and means of ventilation blocked up.

It is thus easy to understand why the maximum prevalence of the disease occurred in the early months of the year; it is less easy to account for the sudden rise in the number of cases in the middle of July 1918. The weather in that month, however, was cold and bleak for the time of the year. The resulting respiratory catarrhs and chills probably favoured the spread of influenza as well as of cerebro-spinal fever infection, while the depressing effects of the former may have rendered the sufferers more prone to the infection of the latter.

Incidence of Attack and Fatality at various Age-groups.—The age distribution of the troops at home is not known, and the population was not a fixed one. Men were continually joining the colours, drafts were being sent overseas in a constant stream, and wounded, sick, and men on leave were returning unceasingly to England. It is, however, probable that the civil male population was more stable, although it was depleted day by day by men joining the army.

In the absence of the necessary data it is not possible to determine the incidence of the disease on soldiers at any given age. Table III shows the actual number of cases that occurred at different ages, the youngest being 14 and the oldest 60 years of age, and the percentage of cases at each age to the total number of cases. It also shows the number of deaths at each age, and the percentage of deaths to cases at the age stated and to the total number of deaths. Similar data are given for age-groups.

The table shows that the greatest number of attacks and deaths (793 and 327 respectively, *i.e.*, 18·7 and 17·0 per cent. of the total number of attacks and deaths) at any age occurred in soldiers aged 18; but the fatality-rate for that age (41·2 per cent.), was slightly lower than the fatality-rate at all ages (45·5 per cent.). It is probable that there was in the home commands a greater number of lads of 18 years of age than of any other age, and that those aged 19 came next in total numerical strength; and that older soldiers were drafted overseas. This might explain why those aged 19 furnished the next highest number of attacks and deaths (namely, 585 and 252 respectively, *i.e.*, 13·8 and 13·1 per cent. of the total number of attacks and deaths). The percentage of fatal cases given in age-groups shows that the disease is increasingly fatal as age increases, and that at the higher ages the fatality-rate approximates to 100·0 per cent.

TABLE III.

Age-incidence of Military Cerebro-spinal Fever Attacks and Deaths in Home Commands, 1914–1918.

Age.	No. of Cases.	No. of Deaths.	Percentage of			Cases.	Deaths.	Fatality.	Percentage of Total.	
			Cases to Total No. of Cases.	Deaths to Cases at the Age stated.	Deaths to Total No. of Deaths.				Cases.	Deaths.
14	2	1	0·0	50·0	0·0					
15	6	4	0·1	66·7	0·2					
16	21	10	0·5	47·6	0·5					
17	70	29	1·7	41·4	1·5	1,475	622	42·2	34·8	32·3
18	793	327	18·7	41·2	17·0	1,378	579	42·7	32·5	30·0
19	585	252	13·8	43·1	13·1					
20	378	152	8·9	40·2	7·9					
21	296	130	7·0	43·9	6·7					
22	245	108	5·8	44·1	5·6					
23	246	111	5·8	45·1	5·8					
24	194	84	4·6	43·3	4·4	1,981	886	44·7	46·8	46·0
25	164	65	3·9	39·6	3·4					
26	146	73	3·4	50·0	3·8					
27	126	53	3·0	42·1	2·7					
28	101	53	2·4	52·5	2·7					
29	85	57	2·0	67·1	3·0					

30	103	54	2·4	52·4	2·8					
31	78	34	1·8	43·6	1·8					
32	68	35	1·6	51·5	1·8					
33	62	36	1·5	58·0	1·9					
34	73	41	1·7	56·2	2·1					
35	78	45	1·8	57·7	2·3					
36	53	33	1·3	62·3	1·7					
37	33	17	0·8	51·5	0·9					
38	46	26	1·1	56·5	1·3					
39	34	13	0·8	38·2	0·7					
40	33	14	0·8	42·4	0·7					
41	28	16	0·7	57·1	0·8					
42	25	16	0·6	64·0	0·8					
43	12	6	0·3	50·0	0·3					
44	12	4	0·3	33·3	0·2					
45	14	11	0·3	78·6	0·6	780	419	53·7	18·4	21·7
46	2	2	0·0	100·0	0·1					
47	5	3	0·1	60·0	0·2					
48	7	3	0·2	42·9	0·2					
49	5	2	0·1	40·0	0·1					
50	4	4	0·1	100·0	0·2					
51	1	1	0·0	100·0	0·1					
52	1	1	0·0	100·0	0·1					
53	—	—	—	—	—					
54	1	—	0·0	—	—					
55	—	—	—	—	—					
56	1	1	0·0	100·0	—					
57	—	—	—	—	—					
58	—	—	—	—	—					
59	—	—	—	—	—					
60	1	1	0·0	100·0	0·1					
Totals ..	4,238	1,928	100·0	45·5	100·0					

Table IV shows a difference which occurred in the number of attacks among soldiers of 18 and 19 years of age in the periods 1914–16 and 1917–18. In the former period the greater number of cases were 19 years of age; in the latter period those of 18 years of age afforded the larger number of cases.

TABLE IV.

Period.	Aged 18.			Aged 19.		
	No. of Cases.	No. of Deaths.	Mortality per cent.	No. of Cases.	No. of Deaths.	Mortality per cent.
1914–15 ..	74	36	48·6	249	123	49·4
1916 ..	50	20	40·0	148	55	37·2
1917 ..	433	177	40·9	122	48	39·3
1918 ..	236	94	39·8	66	26	39·4

The figures are given for comparison in Table V.

TABLE V.

Period.	No. of Cases.		Total Cases at all Ages in the Year.	Percentage of Total Number of Cases in the Year.	
	Aged 18.	Aged 19.		Aged 18.	Aged 19.
1914–15* ..	74	249	1,245	5·9	20·0
1916	50	148	967	5·2	15·3
1917	433	122	1,337	32·4	9·1
1918	236	66	689	34·3	9·6
1914–15 to 1918.	793	585	4,238	18·7	13·8
	1,378			32·5	

* The period 1914–15 is dealt with as one year.

This difference in the attack-rate of lads of 18 and 19 years of age is probably due to the fact that in the first years of the war the number of soldiers aged 18 in the Home Army was much less than it was at a later date. It is interesting to note that while in 1914–15 and 1916 the number of attacks at 18 years of age was 5·9 and 5·2 per cent. respectively of the total cases, in 1917 and 1918 soldiers of 18 years of age furnished 32·4 and 34·3 per cent. respectively of the total cases; and whereas soldiers of 19 years of age provided 20·0 per cent. of the total cases in 1914–15, this percentage dropped in 1916 to 15·3 and in 1917 and 1918 it was 9·1 and 9·6 per cent. respectively.

TABLE VI.

1917 *and* 1918. *Military Cases of Cerebro-spinal Fever. Length of Service at date of onset.*

Command.	Length of Service in Months.					Total under 1 Year.	Length of Service in Years.					Total Cases in Command.
	Under 1 Month.	1—	2—	3 and under 6.	6 and under 12.		1—	2—	3—	4—	5 Years and over.	
Northern	82	105	29	58	66	340	30	22	13	6	5	416
Southern	60	113	31	87	133	424	68	32	14	3	3	544
Eastern	67	114	39	83	81	384	50	32	23	6	7	502
Western	19	34	11	16	11	91	12	12	2	—	4	121
Scottish	15	13	6	13	6	53	9	5	—	1	3	71
Irish	5	17	6	13	6	47	3	5	2	2	1	60
Aldershot	31	24	19	55	36	165	31	6	5	4	3	214
London	15	12	4	13	16	60	10	8	4	—	2	84
Channel Islands	—	—	—	2	1	3	—	1	—	—	—	4
Total..	294	432	145	340	356	1,567	213	123	63	22	28	2,016*
Percentage of Total ..	14·6	21·4	7·2	16·9	17·6	77·7	10·6	6·1	3·1	1·1	1·4	100

* The total cases occurring in 1917 and 1918 amounted to 2,026. Particulars as to length of service of 10 of these cases (5 in Southern Command, 2 in Western Command, 2 in Scottish Command and 1 in London District) are unobtainable.

TABLE VII.

1917. *Military Cases of Cerebro-spinal Fever. Length of Service at date of onset.*

Command.	Length of Service in Months.					Total under 1 Year.	Length of Service in Years.					Total Cases in Command.
	Under 1 Month.	1—	2—	3 and under 6.	6 and under 12.		1—	2—	3—	4—	5 Years and over.	
Northern	69	80	15	33	37	234	20	15	6	4	5	284
Southern	48	95	24	61	92	320	52	23	2	2	3	402
Eastern	60	88	27	50	48	273	32	19	8	1	6	339
Western	16	28	11	8	8	71	11	8	1	—	3	94
Scottish	2	2	3	7	4	18	8	3	—	—	3	32
Irish	1	2	—	6	1	10	1	3	1	—	—	15
Aldershot	23	15	5	11	21	75	20	3	—	—	1	99
London	11	10	3	11	12	47	7	7	1	—	1	63
Channel Islands	—	—	—	1	—	1	—	1	—	—	—	2
Total..	230	320	88	188	223	1,049	151	82	19	7	22	1,330*
Percentage of Total ..	17·3	24·1	6·6	14·1	16·8	78·9	11·3	6·2	1·4	0·5	1·7	100

* The total cases occurring in 1917 amounted to 1,337. Particulars as to length of service of 7 of these cases (4 in Southern Command, 2 in Scottish Command, and 1 in London District) are unobtainable.

TABLE VIII.

1918. *Military Cases of Cerebro-spinal Fever. Length of Service at date of onset.*

Command.	Length of Service in Months.					Total under 1 Year.	Length of Service in Years.					Total Cases in Command.
	Under 1 Month.	1—	2—	3 and under 6.	6 and under 12.		1—	2—	3—	4—	5 Years and over.	
Northern	13	25	14	25	29	106	10	7	7	2	—	132
Southern	12	18	7	26	41	104	16	9	12	1	—	142
Eastern	7	26	12	33	33	111	18	13	15	5	1	163
Western	3	6	—	8	3	20	1	4	1	—	1	27
Scottish	13	11	3	6	2	35	1	2	—	1	—	39
Irish	4	15	6	7	5	37	2	2	1	2	1	45
Aldershot	8	9	14	44	15	90	11	3	5	4	2	115
London	4	2	1	2	4	13	3	1	3	—	1	21
Channel Islands	—	—	—	1	1	2	—	—	—	—	—	2
Total..	64	112	57	152	133	518	62	41	44	15	6	686*
Percentage of Total ..	9·3	16·3	8·3	22·2	19·4	75·5	9·0	6·0	6·4	2·2	0·9	100

* The total cases occurring in 1918 amounted to 689. Particulars as to length of service of 3 of these cases (2 in Western Command and 1 in Southern Command) are unobtainable.

Length of Military Service as a Factor in determining an Attack.—A large proportion of cases occurred among recruits during the first few weeks of their service, and it appeared probable that recruits acquired an increasing immunity as time went on.*

Tables VI, VII, and VIII, subdivided for commands, give the length of military service of those attacked in the years 1917 and 1918, separately and together. Corresponding data for the earlier years of the war were not abstracted.

These tables show for the two years in question that 36 per cent. of the cases occurred among recruits of less than three months' service, and that 77·7 per cent. of the cases had less than one year's service.

Comparison of Attack and Fatality on Soldiers and Civil Male Population at certain Age-groups.—The number of cases and deaths occurring in certain age-groups, the fatality-rate, and the percentage of cases and deaths to the total cases and total deaths respectively, occurring in the military population for the period 1914–15 to 1918 are given in the following table. Two cases and one death are omitted; they occurred in boys of 14 years of age. The corresponding data relating to males in the civil population are given for comparison.

TABLE IX.

Age-group.		Cases.	Deaths.	Fatality.	Percentage of Total.	
					Cases.	Deaths.
15–19 ..	Military	1,475	622	42·2	34·8	32·3
	Civil ..	382	233	61·0	37·3	34·9
20–29 ..	Military	1,981	886	44·7	46·8	46·0
	Civil ..	241	145	60·2	23·5	21·7
30 and upwards	Military	780	419	53·7	18·4	21·7
	Civil ..	402	290	72·1	39·2	43·4
At all ages above 14.	Military	4,236	1,927	45·5		
	Civil ..	1,025	668	65·2		

Owing to the impossibility of making any estimate of the number of civilian males in the age-groups quoted above no reliable deduction can be made with regard to the total number of such cases in the several age-groups. It is probably certain

* The age of the patients at the time of attack is given in Table III.

that the majority of males between 18 and 30 were serving in the army and that the remaining civilians were in the main physically unfit for the life of a soldier. It will, however, be seen that the total number of civilian cases was greater at those age-periods in which the greater number of military cases occurred. But the most striking feature is the higher fatality among the civilians when compared with the military fatality at each age-group. If it be granted that the military population could be classed as "fit" and the civilian population as "unfit," this might in some measure account for the higher fatality-rate in the latter, but even this would hardly account for the difference between the total military fatality-rate of 45·5 per cent. and the total civilian rate of 65·2 per cent.

As regards the military cases of cerebro-spinal fever, in the first year of the war 49·6 per cent. of those attacked died. In the last year of the war 41·8 per cent. of those attacked died. The total cases were 4,238; of these 45·5 per cent. died, namely, 1,928. If 49·6 per cent. of the 4,238 cases had died the number of deaths would have been 2,102. If 41·8 per cent. of the 4,238 cases had died the number of deaths would have been 1,771. The number of lives saved at this latter rate would be 331. This would represent a total saving of 7·8 per cent. If the 4,238 cases had had a death-rate that the civil population had, *i.e.*, 65·2 per cent., the total deaths would have been 2,763.

In considering the fatality-rate of the military and civil population, it should be remembered that after the first few months of the war military medical officers were constantly on the look-out for cases of cerebro-spinal fever, and although it is true that in a certain proportion of cases the true nature of the illness was not at first recognized, with the result that these cases did not come under prompt treatment, yet it must be borne in mind that a very large number of cases were provisionally diagnosed as cases of cerebro-spinal fever and sent as such into hospital, where the patients were found to be suffering from some other ailment. It is, of course, not possible to state with any degree of accuracy the proportion which these cases bore to the total number of true cases, but the experience of the hospital at Salisbury seems to indicate that the army medical officers promptly sent to hospital any suspected cases of cerebro-spinal fever, with the result that comparatively few true cases were overlooked, both severe and mild cases coming under treatment.

On the other hand, the civil population was depleted of medical practitioners and such as remained were overworked,

and it is probable that many mild cases were never correctly diagnosed, whereas the severe cases would from their very severity force themselves upon the notice of the medical practitioner. Comparatively few cases were admitted to isolation hospitals; some were taken to general hospitals, but the bulk of the cases were treated at home, where the nursing arrangements would fall short of the standard attained in hospitals. There was always a difficulty in procuring anti-meningococcus serum for the treatment of the civilian sick and it was almost unobtainable in rural districts. Moreover, a number of medical practitioners hesitated to perform lumbar puncture, and bacteriological confirmation of the diagnosis was frequently lacking.

It may safely be said that on the whole the military cases, although on occasion they were taken long distances to hospital, were treated under better conditions, both as regards bacteriological verification of diagnosis with its resulting more accurate treatment, skilled medical supervision and nursing, than the civilian cases, and to this extent they had a better chance of recovery. The result is illustrated in the difference between the military fatality-rate and the civil fatality-rate for males at approximately the same age-period, taken over the period of the war.

When it is considered that the total number of troops at home in the four years ran into millions it will be realized that the total number of cases of cerebro-spinal fever, 4,238, is comparatively small.

Conclusions.

The total number of cases of cerebro-spinal fever compared with the total number of cases of sickness in the army at home was remarkably few and compared favourably with the number of cases of certain other communicable diseases. The loss of military efficiency due to it was almost negligible. Against this has to be set off the time lost from military training by the segregation of contacts and carriers, the expense of maintaining a trained expert medical staff, albeit the duties of very few of this staff were confined solely to dealing with cerebro-spinal cases. Within certain limits the prevalence or absence of cerebro-spinal fever can be regarded as an index to the sanitary condition of the troops, and the general effect of improving the hygienic surroundings of the troops entailed in the special precautions taken against cerebro-spinal fever operated favourably on the health of the troops as a whole.

The army arrangements for mobilization were based on an assumption that troops recalled to the colours from the reserve and recruits joining could in the main be accommodated in existing barracks and under canvas, and that during the preparation of the expeditionary force for service overseas, variously estimated at a fortnight to a month, the amount of cubic space per man in barracks—600 cub. ft.—could be temporarily reduced to 400 cub. ft. without much inconvenience, and that matters would right themselves when the expeditionary force had sailed. The magnitude of the task before the country completely upset these calculations. From the beginning the permanent barracks were overcrowded, and as the hutments were erected and new camps formed they in turn became overcrowded. Moreover, lack of wood and other materials and the shortage of labour prevented the required amount of housing accommodation being provided. The mobilization scale of 400 cub. ft. per man became the service standard, and even this was reduced on occasions of pressure when large numbers of troops were drafted into a camp. Even when a camp could accommodate the number in the draft, had the men been equally distributed, it frequently happened that there was temporary overcrowding for a few days while the men were being spaced out.

Following mobilization and the gathering of young men together in large numbers under conditions of adverse weather, insufficient accommodation, imperfect clothing arrangements, and defective cooking, there followed the first year's seasonal rise of cerebro-spinal fever. In the second year, though recruits were still joining the army, the troops were in some measure more seasoned, better housed, clothed and fed, and included a certain number who, from one cause or another, had returned from overseas, and the seasonal curve of cerebro-spinal fever was much lower than was the case in the first year. With the third year came the effect of the Military Service Act and recruits again joined the army in large numbers and the adverse circumstances of the first year were repeated, but not to the same extent, as the emergency work of the first year had ceased and the camps had become organized and old soldiers were available to teach the newcomers. However, while less in proportion to the total number of troops at home the total number of cases of cerebro-spinal fever that occurred was greater than in the first year. The fourth year was comparatively free from sudden incursions of large drafts of recruits into the army, and in general the working arrangements

of the camps were proceeding smoothly and efficiently and the number of cases of cerebro-spinal fever was the lowest recorded in the four years.

The 4,238 cases of cerebro-spinal fever among troops spread over four years represents an average of approximately 1,060 for each year, and if the total number of troops at home at any one time is estimated at 1,588,000, this would represent an annual attack-rate of 0·668 per 1,000. It cannot be said that this rate is in any way excessive. Taking the experience of past outbreaks among troops it may be considered to be small and almost insignificant. It remains to be considered whether the result attained is commensurate with the expenditure of time, money and effort.

It is, of course, not possible to conjecture what the attack-rate would have been had no administrative steps been taken to control the disease, but it may be said with safety that it would have been higher than it was; there are no means of estimating how much higher it might have been.

At the commencement, little knowledge of the disease was possessed; it was considered that safety should be aimed at even if the steps taken were likely to prove in excess of those actually required rather than run any risks that might prejudice adversely the health of the troops.

In deciding on measures for checking the disease prevalence, the exigencies of the military situation had ever to be considered and action determined on lines that would cause the least disorganization of troops in training.

From the first the administrative procedure was based on the supposition that in the main the disease spreads from person to person, and that persons otherwise in good health may harbour the infection in their naso-pharynx and be, in fact, carriers, and may be the means of spreading the disease to others and in its meningeal form. The experience gained through the years of war fully endorsed this provisional assumption, and no main principle had to be altered, although readjustments were necessary to meet the altering conditions. That minor errors were made is admitted, but when they were discovered the cause of failure was sought out and corrected. The story of the steps taken to deal with the disease is one of continual progress in efficiency, resulting from close attention to detail and study of the subject by many workers in the field and in the laboratory. The result must be regarded with satisfaction.

At the outbreak of the war there were many medical officers who had spent years in the study of epidemiology and in close association with troops, and who were well acquainted with the Report of the Commission appointed in May 1857 to enquire into the regulations affecting the sanitary condition of the army, the organization of military hospitals, and the treatment of the sick and wounded, and the Report of the Commission appointed in October 1857 for improving the sanitary condition of barracks and hospitals. The fifth instruction to the latter Commission runs, "You are further instructed to allot the existing accommodation in all barracks and hospitals, so far as it may be practicable so to do, in such manner that not less than 600 cub. ft. be provided for every man in barracks and guard-rooms, while at least three feet shall intervene between every two beds in the former, and that in hospitals a cubic space of at least 1,200 cub. ft. be allowed for each bed, and at least four feet between the sides of the beds, and 12 ft. from foot to foot when practicable." It is thought that, had it been possible at mobilization and subsequently during the period of the war to carry out this instruction in its entirety, little else would have been required to deal with cerebro-spinal fever among the troops, for there would have been but few cases of the disease. The instruction drawn up fifty-seven years before the war was based on knowledge acquired by experience. Subsequent advances in science have furnished explanation of phenomena then observed, and demonstrated the soundness of the instruction, which the experience gained during the war only serves to emphasize and to establish for future guidance.

BIBLIOGRAPHY.

Glover	The Cerebro-spinal Fever Epidemic at "X" Depôt.	Jl. of R.A.M.C., 1918, Vol. xxx, p. 23.
"	"Spacing out" in the Prevention of Military Epidemics of Cerebro-spinal Fever.	Br. Med. Jl., 1918, Vol. ii, p. 509.
"	Observations on the Meningococcus Carrier-rate in relation to Density of Population in Sleeping Quarters.	Jl. of Hyg., 1918, Vol. xvii, pp. 367–379.
"	Cases of Cerebro-spinal Fever definitely traceable to a particular Carrier.	Lancet, 1918, Vol. ii, p. 422.
"	Observations of the Meningococcus Carrier-rate and their Application to the Prevention of Cerebro-spinal Fever.	M.R.C., Spec. Rep., Ser. No. 50. Lond., 1920, p. 133.

BIBLIOGRAPHY—*cont.*

Gordon, J. E. ..	Cerebro-spinal Fever: Notes on 251 Cases treated at the Salisbury Isolation Hospital.	Jl. of R.A.M.C., 1918, Vol. xxxi, pp. 90–95.
Reece	Notes on the Prevalence of Cerebro-spinal Fever among the Civil Population of England and Wales, etc.	Jl. of R.A.M.C., 1915, Vol. xxiv, pp. 555–568.
Official	Do. do.	Report for 1917–18 of the Medical Officer of the Local Government Board, pp. 55–56, and Appendix 3.
"	Do. do.	Report for 1918–19 of the Med. Dept. of the Local Government Board, pp. 48–52, and Section 4.
"	Bacteriological Studies in the Pathology and Preventive Control of Cerebro-spinal Fever among the Forces during 1915 and 1916.	Medical Research Committee, Special Report Series No. 3. Lond. 1917.

CHAPTER X.

PREVENTION OF TRENCH FOOT.

THE incidence, ætiology, symptoms, and treatment of trench foot are described in the first volume of the Surgery of the War. The details of preventive measures come within the sphere of the hygiene of the war, and an account of these consequently has its place here.

The condition was the cause of an immense amount of inefficiency during the winter of 1914–15, and in subsequent winters whenever precautionary measures were neglected or impracticable.

The measures for preventing it were directed along the following lines. In general, prevention consists in maintaining the men in as fit a condition as possible and in exercising as wide an hygienic control over them as is compatible with the conditions of trench warfare. The particular measures of prevention are summed up in the protection of the feet and legs from mud and wet ; keeping them dry, warm, and clean ; making, in fact, a fine art of the " toilet " of the feet ; improving the condition of the trenches ; and providing the men in them with hot food. The application of foot powders and foot grease, a variety of which has been recommended, is only accessory to the toilet of the feet and not essential.

Improvements in the condition of the trenches were first in importance. Active and systematic steps were taken to keep the trenches as dry as possible ; and where there is a possibility of trench warfare in a temperate climate, stress should be laid on the necessity of improving and perfecting the organization for the supply of such devices as pumps, trench boards, expanded metal or other materials for revetments, which will lessen or obviate the necessity of troops having to stand in wet and mud.

In order to protect the troops from mud and wet special clothing and special boots were issued. Troops had never been so well clothed in any previous campaign, and in spite of the severity of the weather, men still found it possible to keep their bodies warm. But large sizes of service boots were found necessary to counteract the shrinkage caused by constant wet, and also to allow men to wear two pairs of socks. Waterproof paper waders of various patterns were

given an extensive trial during the latter months of the winter of 1914–15, and although they were of some benefit, they were not sufficiently durable and were replaced by gum boots with thigh extensions. Gum boots will protect the wearer against mud, and also against water, if their use is understood. In order to avoid the necessity of walking a greater distance than necessary in impermeable boots, the gum boot stores, where the articles were issued to the men, and where they left their service boots, were situated as near as possible to the firing line. In exceptional cases these stores were located as near as 1,000 yards from the front line, in a dugout excavated from the solid chalk. As a general rule they were much farther back, 5,000 yards or more. When gum boots are used for marching, apart from the risk of chafes and abrasions, the inside of the boots become wet from condensed perspiration, while the woollen pants and breeches or trousers, protected by the india-rubber extension, became soaked from the same cause, so that the legs and feet were subjected to the very conditions that the boots were devised to avoid.

Gum boots had to be dry inside when re-issued from the stores. The following method for effecting this was tried with success: A piece of iron piping about 6 ft. long was placed across a lighted brazier. At one end of it a length of rubber tubing was fitted which was placed inside the boot. The nozzle of a hand bellows was closely fitted to the other end. When the iron piping was heated, hot air was blown right to the toe end of the boot through the rubber tubing. Improved means, however, were still required for drying large numbers of these articles within a reasonable time, and there was a demand for some device for driving hot dry air through a dozen or more pairs of boots at once.

Two pairs of woollen socks were recommended to be worn; the moisture of the foot is condensed in the outer sock, while the inner sock remains comparatively dry. Gum boots had therefore to be sufficiently large to allow of two pairs of socks being worn in comfort. If the straps at the ankle were carefully adjusted, the wearer was able to walk without the heel slipping up and down inside the boot. It was further advisable that the boots should not be worn continuously for more than thirty-six hours. When the trenches were knee-deep in semi-liquid mud, and there were no shelters or dugouts, removing gum boots and attending to the toilet of the feet were difficult or impossible. The only alternative was to relieve the troops or run the risk of a large increase in the number of cases of

trench foot. Many officers stated that they experienced the greatest benefit from gum boots when they put them on after arriving in the trenches. They preferred to walk up in ordinary boots and change after reaching their destination in the trenches.

The development of the arrangements for the supply of socks to men in the trenches was another of the measures for preventing trench foot. It entailed the organization of institutions under the charge of the "baths officer" known as the "divisional sock stores." Waterproof sacks or bags full of clean dry woollen socks were sent up from the sock stores every night to the trenches with the rations, in sufficient numbers to allow every man to have a fresh pair of socks every twenty-four hours. The dirty socks were sent down by the same route, and were collected and despatched to laundries daily.

The maintenance of the circulation and the prevention of any form of constriction of the feet and legs considerably lessened the liability to trench foot. It was the interference with circulation combined with wet and cold which was specially to be avoided. Although the Indian cultivator works day after day in liquid mud in his rice-fields he does not suffer from trench foot. He does not wear tight boots or constricting puttees, and when working he is constantly on the move and believes in frequent intervals for rest. There is little or nothing to impair the normal circulation in his feet.

In order to maintain circulation the men were encouraged to move about when in the trenches, and the danger of standing still for long periods was pointed out. Other measures were the regular removal of the boots, with foot-rubbing drills and massage.

Rest and recuperation in a correct posture while off duty were important factors in preventing trench foot. During "stand to" all troops in the trenches are on the alert and on duty. On ordinary occasions, however, the time is divided up into periods of "on" and "off" duty. The decrease or increase in the incidence of trench foot depended upon whether the best use was made of the time off duty or the reverse. If the men were left to themselves and were allowed to spend the time standing, or in a crouching position against the wet side of a trench, or sitting on the fire step, then the time off duty increased instead of diminished their liability to trench foot. Captain B. Hughes, writing of his experience as a regimental

medical officer in the trenches, pointed out that although the men were provided with the means for preventing trench foot, cases still occurred which he attributed to the common practice the men had of sleeping when off duty in a sitting posture on the fire step of the trench. The sharp edge of the fire step exerted pressure over the popliteal space and in this way produced numbness and coldness of the feet. When men were on duty in pairs, he arranged that the man whose turn it was to rest should lie with his feet up on the fire step, and sleep in his greatcoat and two blankets, his own and that of his comrade. The result of these measures was that during a period of twelve days of inclement weather in the trenches no cases of trench foot occurred in the battalion of which he had medical charge, while the unit which occupied the same trenches previously had several cases.

It was common experience that amongst men who were kept standing in cold mud for longer periods than thirty-six hours the incidence of trench foot increased out of all proportion. Consequently the tour of duty in a water-logged sector should not exceed twenty-four to thirty-six hours.

The supply of a liberal ration of hot food in the trenches undoubtedly did much to counteract the harmful effects of exposure. When the importance of providing hot food in the trenches was realized, special containers were devised on the principle of the hay-box for keeping the cooked rations hot. The ordinary camp kettle full of hot stew was placed in a nest of hay or straw in a box, which was then slung on a pole and carried by two men of the ration party up to the trenches. After the soldier filled his mess-tin he was able to heat up his portion of warm stew by means of a "Tommy's cooker," a small stove in which "solidified alcohol" was burned. There was a constant demand for these cookers. Brigade soup kitchens were organized also, and were located close to the gum boot stores, where men were given a mug of hot soup while changing their boots. Similarly, troops coming out of the trenches were served with hot soup at the same place. Some "depôts" of the Y.M.C.A. were also established in small dugouts where hot drinks could be obtained in the reserve trenches.

Experiments were made with foot grease and foot powders as a prevention against trench foot. Mineral jelly, animal fat, and "anti-frostbite" grease, composed of whale oil, tallow and boric acid, were used in large quantities, but were given up in favour of whale oil, which proved a valuable means

of protecting the skin when gum boots were not available. It was not sufficient merely to apply these preparations to the feet; they had to be rubbed in until the skin was practically dry. The beneficial results obtained were no doubt largely due to the improvement in the circulation of the feet owing to the rubbing.

The objections to whale oil were its offensive smell and uncleanliness. When in the trenches, men rubbed their feet daily with whale oil, and as it was at that time impossible for them to wash their feet, they were obliged to rub a certain amount of trench mud with the oil. Another objection was the difficulty of washing socks impregnated with this mixture of mud and oil. As experience increased, better results were obtained by abandoning all greasy preparations, and by employing the more cleanly method of prevention advocated by Médecins-Majors Reymond and Parisot of the French Army. Before going into the trenches the men washed and dried their feet thoroughly and applied a foot powder of borated talc and camphor, then put on socks dusted inside with the same powder. When in the trenches they wore gum boots and were provided with a daily change of clean socks.

As regards the quantities of the various applications for the feet, 10 gallons of whale oil was the daily issue for one battalion when in the line. One ton of anti-frostbite grease was the daily amount issued to each army corps of the Second Army. The quantities of the ingredients required for carrying out the French method, per division per week, were :—

Soft soap	300 lb.
Camphor	22 „
Sodium borate	35 „
Talc powder	500 „

Facilities for changing socks, washing feet with hot water and cleansing with soap and nailbrush were provided under conditions of comparative comfort by the institution of "foot-washing centres." These centres were an unqualified success, and constituted an important link in the chain of preventive measures, much appreciated by all ranks.

After leaving the trenches no time should be lost in making the men as comfortable as possible; their clothes should be dried and arrangements made for baths and a change of clean clothing. It should be remembered that as much harm may result from men waiting about in billets with sodden boots and socks as if they were actually in the trenches.

The principles of prevention were laid down in General Routine and Standing Orders and commanding officers were responsible that the instructions were carried out. Examples of these, showing the development of the measures adopted, are given in Appendix C.

An army routine order was published in the First Army in January 1915 to the effect that measures were to be taken by regimental and company officers to ensure that every men should have an extra pair of dry socks with him and that he should be made to remove his boots at least once in twenty-four hours, dry and rub his feet and put on dry socks in place of those discarded. Boots were also to be kept greased.

The result was immediate and trench foot practically disappeared from all divisions in the army, except one. When an enquiry was made into the cause of the failure in this division it was found that the battalion medical officer and not the company officer had been made responsible in divisional orders for carrying out the preventive measures. When this was rectified good results were at once obtained. This incident serves to emphasize the importance of placing the responsibility for the proper care of the men's feet on the company and platoon officer.

It has been established beyond dispute that trench foot can be prevented, and if the principles of prevention are grasped and the details carried out with thoroughness and energy success is assured.

CHAPTER XI.

PREVENTION OF FLIES.

THE subject of flies in their relation to the spread of disease was one which had assumed considerable prominence before the war, and the necessity of adopting rigid anti-fly measures to protect the troops in the various theatres of war received early recognition from the responsible medical authorities. In the East, indeed, the fly problem soon came to be regarded as one of the most important sanitary problems to be solved. Much anxious thought and energy were devoted by sanitary officers to investigations into the habits of flies and into methods of destruction of both the mature and immature insect. As the result of this work new knowledge was acquired and greatly improved methods of fly control were devised, which in turn reacted on the health of the troops and caused a marked reduction in fly-borne diseases in the later stages of the war.

Before the war there was a considerable body of evidence incriminating the house-fly as a carrier of disease, and this evidence amounted to positive proof in the case of enteric fever, cholera, and dysentery. Strong evidence was forthcoming that infantile diarrhœa and ophthalmia might also be carried by flies, and it had been proved experimentally that the house-fly was capable of carrying *B. enteritidis* (Gaertner) for eight days, *B. prodigiosus* up to seventeen days, *B. tuberculosis* when infected by feeding on infected sputum, for seven days, *B. anthrax* for five days and anthrax spores for at least twenty days, *B. diphtheria* for twenty-four hours and occasionally longer.

In 1916 investigations were made in Egypt with a view to discovering the rôle which flies play in the spread of dysentery. Captain J. Gordon Thomson, R.A.M.C., fed flies on fæces containing a large number of cysts of *Entamoeba tetragena*. Eighteen hours afterwards the flies were dissected and large numbers of these cysts were found in their intestines.

Working at the same time under the Advisory Committee for the Prevention of Epidemic Diseases, Mediterranean Expeditionary Force, Wenyon and Connor conducted a more exhaustive search into the carriage by flies of *Entamoeba histolytica* and other intestinal protozoa and eggs of parasitic worms.

Experimenting with house-flies (*Musca* and *Fannia*), with the blue-bottle fly (*Calliphora*) and the green-bottle fly (*Lucilia*), these observers were able readily to confirm Kuenen and Swellengrebel's work in Sumatra, in which they showed that flies fed on infected fæces ingested cysts of *E. histolytica*.

Wenyon and Connor further observed that the cysts remained recognizable in the gut of the fly as long as fæces were present, but that they vanished with the disappearance of fæcal matter from the fly's intestine. Within twenty to thirty minutes after feeding the flies began to deposit droplets of liquid fæces, and in these droplets unaltered and living cysts were easily found. Cysts could be found in the fæces of flies twenty-four hours after a meal on infected fæces, and in one case cysts of *E. coli* were found so long as forty-two hours after the last feed.

The fæces of 200 wild house-flies caught at random at Alexandria were also examined. It was evident that many of them had been feeding on human fæces, and in the droppings of fifteen were found not only the cysts of *E. histolytica*, *E. coli*, and *Lamblia intestinalis*, but also the oöcyst of a coccidium and eggs of the various parasitic worms, *Taenia saginata*, *Ankylostoma duodenale*, *Trichiuris trichiura*, *Heterophyes heterophyes*, and the comparatively enormous lateral-spined egg of bilharzia.

These observers therefore concluded that flies under natural conditions were actively concerned in the carriage of the cysts of *E. histolytica* and other organisms, and that the chief method of conveyance was by their fæces, as they were unable to demonstrate cysts in the fluid regurgitated.

In 1917 Dudgeon examined 100 flies caught in a dysentery hospital in Salonika. From one of these, caught in a kitchen, he recovered a typical Flexner bacillus.

A careful investigation into the extent to which house-flies actually carry pathogenic organisms was carried out at Amara in Mesopotamia by Captain P. A. Buxton from 1st February to 3rd November, 1918. He dissected 1,027 flies and found that of these 645 (63 per cent.) contained " apparent fæces," 42 (4·09 per cent.) contained human intestinal parasites, and 3 (0·3 per cent.) contained cysts of *E. histolytica*. "Apparent fæces " were recorded when the gut contained brownish material enough to be seen by the naked eye, which material agreed in its microscopical appearance with human fæces. He found also that male flies were much cleaner than female flies—65 per cent. of the latter containing "apparent fæces," while only 33 per cent. of male flies presented this feature, and then in a lesser degree.

Dealing with female flies only, it was found that the proportion of flies containing apparent fæces varied with the sanitary conditions of the area in which they were caught, from 39 per cent. in the neighbourhood of British latrines without incinerators to 80 per cent. in Arab compounds where the sanitation was of a very primitive kind. It was noticed that the proportion of dirty flies was higher where incinerators were provided at British latrines than where there were none. This, he explained, was due to the fact that numbers of flies might frequently be seen inside the incinerator feeding on such material as was not directly in the smoke. He concluded from this that incinerators constructed without a door, and *a fortiori* open incinerators, are to be condemned as a serious leak in the sanitary system.

In conclusion, he felt justified in regarding the fly in Mesopotamia as not only a potential but an actual and major factor in the carriage of the bowel disorders which were so prevalent in that country.

Captain F. F. Taylor, R.A.M.C., in writing on the rôle of the fly as a carrier of bacillary dysentery in Macedonia, showed that the periods of the year when bacillary dysentery assumed a greater prevalence—spring to early summer and late summer to early autumn—coincided with periods when the fly pest was at its worst. (Chart I.)

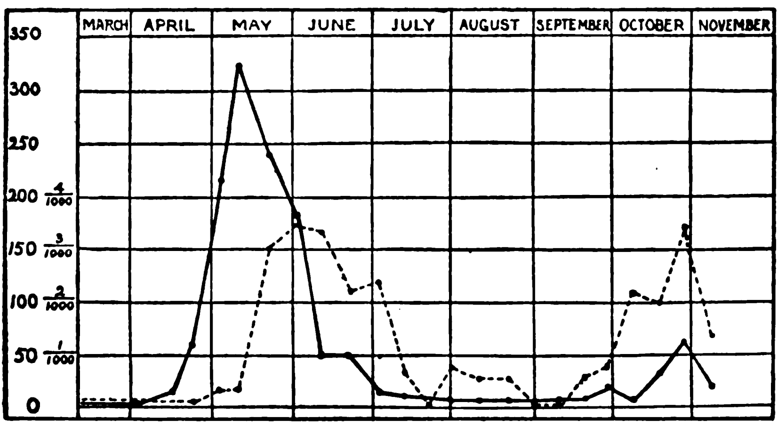


Chart I.—Showing the correlation between flies and dysentery in Salonika.

———— Flies per trap per day.

– – – – – Dysentery cases per 1,000 admissions for sickness daily.

Experiments proved conclusively that flies, when deliberately infected with a bacillus of the dysentery group, were able to carry that bacillus and to infect suitable media with it for at least twenty-four hours. Growths of bacilli were obtained, when an infected fly was allowed to walk about on a culture

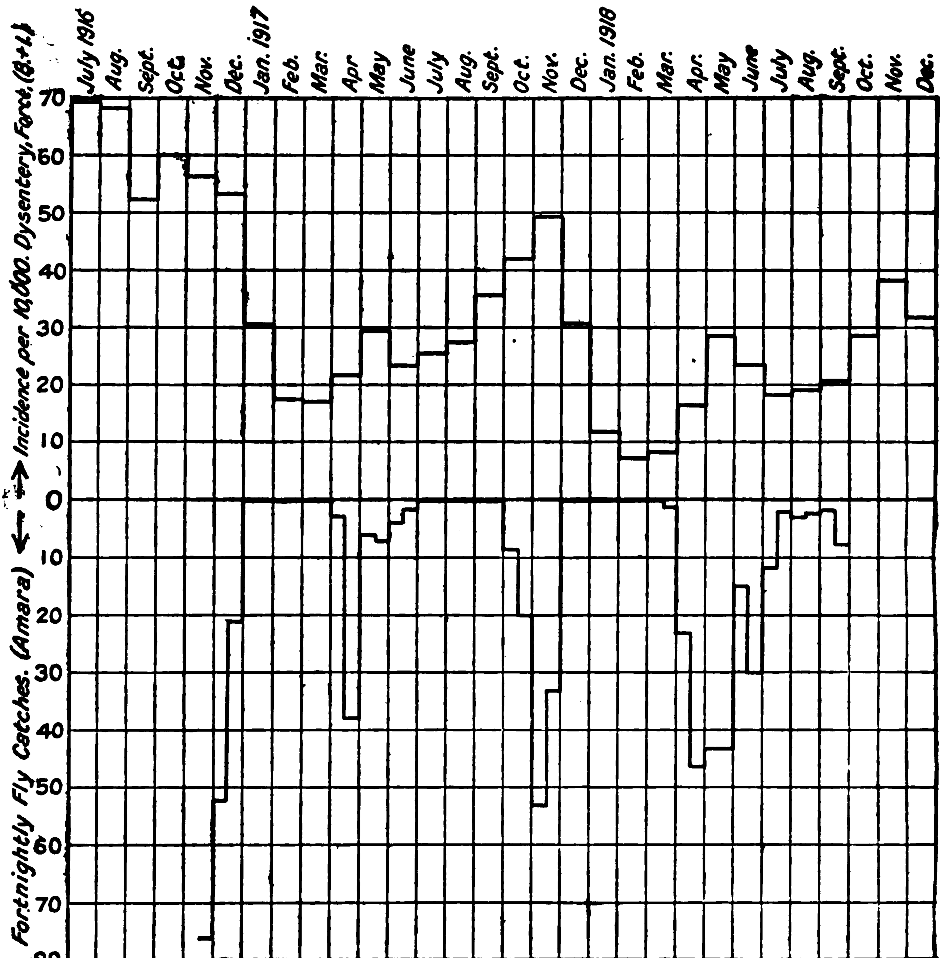


Chart II.

plate, in the fæcal deposit of infected flies, and from the detached legs of flies which had been allowed to walk on infected material.

Experiments were also carried out which showed that flies in their natural state were capable of carrying dysentery bacilli.

In Mesopotamia the same close correspondence between the incidence of dysentery and the prevalence of flies was recorded by Lieut.-Colonel J. C. G. Ledingham, R.A.M.C. (Chart II.) He stated that practically no flies were caught during the first quarter of the year. The first broods appeared in the last fortnight of March or the first fortnight of April, and the maximal catches were recorded in the last fortnight of April or the first fortnight of May. During July and August, the hottest months of the Mesopotamian year, the flies all but disappeared, to reappear again the last fortnight of September or the first fortnight of October. The autumnal fly prevalence had its maximum in the first or second fortnight of November.

He pointed out, further, that the almost complete disappearance of flies in the hot months was not accompanied by any proportionate fall in the dysentery prevalence, which returned only to the April level. He inferred that other factors than flies played the more important rôle in distributing infection during this period, and suggested that the mass of fresh infections established in the spring outbreak largely by the agency of flies left behind it a large amount of chronic and carrier infection which, aided by the weather conditions favouring intestinal disturbance, served to maintain the dysentery and diarrhœa incidence at a fairly constant level till the next fly outburst initiated the autumnal mass of fresh infections.

There was therefore a considerable weight of evidence incriminating the fly as an important agent in the spread of disease, and as a serious menace to the health of troops in the field, more especially as a carrier of intestinal diseases—cholera, enteric fevers, and both the amœbic and the bacillary varieties of dysentery.

A practical demonstration of the association of flies with dysentery was afforded by the epidemic of the disease among the forces on the Gallipoli peninsula in the summer of 1915. Owing to the insanitary conditions prevailing in the overcrowded area held by the British troops, conditions largely due to the difficulty of carrying out sanitary measures under constant shell fire, flies multiplied to such an extent as to become a veritable plague and to make life a burden to man and beast.

They pestered men and animals unceasingly, and the instant any food was exposed it was immediately covered with a black swarm of flies. Dysentery, the inevitable consequence, soon broke out, and increased so rapidly that the base hospitals in Mudros, Egypt, and Malta were filled to overflowing with

its victims, and many hundreds were invalided home. In addition to the thousands of cases that found their way to the base hospitals, there were many more who managed to carry on with their duties though suffering more or less chronically from diarrhœa which was undoubtedly dysenteric in nature.

A few cases of enteric fever, chiefly paratyphoids, also occurred, but this group of disease was effectively kept in check by inoculation. Cholera, fortunately, did not appear.

This outbreak of dysentery, disastrous as it was, had one beneficial effect. It not only focussed the attention of sanitary officers in the Middle East on the importance of the fly problem, but it brought home to combatant officers and men the danger of the spread of disease by flies, as well as the intense discomfort which they caused when present in large numbers. From this time onwards the prevention of fly-breeding and the destruction of flies became one of the most anxious problems of those responsible for the sanitation of the troops in the East.

Some points in the life-history of the house-fly are of importance as they indicate the methods for their destruction.

The female fly deposits her eggs in such material as will provide food and shelter for the future maggots. Moisture and warmth are essential factors in the life of these larvæ, and therefore the eggs are laid in places where warmth and moisture as well as an adequate supply of suitable food are assured. The favourite breeding places are therefore moist horse manure, human fæces, and decaying organic matter. In such situations, if breeding is not interfered with, masses of flies' eggs may be discovered. A single house-fly lays from 120 to 150 eggs at one time and may deposit five or six such batches during its life, so that each female may produce from 600 to 900 eggs.

The maggot or larva hatches out from the egg in from eight hours to three days, according to the temperature, and attains its full development in from forty-two hours to four or five days in hot weather. In cold weather it may take as much as six to eight weeks to reach maturity.

When fully developed the larvæ leave the manure heap or other food in which they have hitherto lain concealed and, travelling at night, make their way to its edge, where they burrow into the soil to a varying depth not exceeding 2 ft. If the larvæ have developed in a latrine trench they burrow upwards through the soil until they arrive near the surface where they come to rest, and the change to the pupa state takes place. It has been ascertained that larvæ are capable

of making their way to the surface through as much as 6 ft. of loose sand. As illustrating the numbers of larvæ which may develop in a suitable nidus, it is interesting to note that in northern Sinai in December 1916 no fewer than 3,226 larvæ were found by Major Austen in one deposit of human fæces.

The pupa hatches out into the adult fly after a period lasting from three days to four weeks or more, the length of time depending on the temperature.

The period therefore which elapses between the laying of an egg and the emergence of the adult fly varies according to the temperature from a minimum of six days to twelve weeks or even longer. In fact, as has been shown by Captain R. P. McDonnell and Staff-Sergeant T. Eastwood, the larvæ and pupæ of *M. domestica* and *Fannia canicularis* may remain in old manure heaps and latrine trenches throughout the winter, and complete their metamorphosis in the following spring.

In Western Europe the adult fly is capable of laying eggs after a period of from fourteen to eighteen days from its emergence from the puparium ; in warmer climates the period is often considerably shorter, and, as already stated, it is able to lay five or six batches in all. The progeny of a single fly is simply phenomenal, and it has been estimated that, if the numbers were not reduced by natural causes, one fly would be the ancestress of about 5,598,700,000,000 in the course of six months. Flies have many enemies, however, in the shape of birds, spiders, lizards, and other animals, while a parasitic fungus (*Empusa muscae*) kills off large numbers of house-flies every autumn.

The breeding of flies is greatly inhibited by intense heat accompanied by excessive dryness of the air, conditions which are found in northern India, Egypt, Palestine, and Macedonia during the summer months. In these countries the extreme heat and dryness rapidly desiccate manure and other materials in which flies breed, with the result that the moisture necessary for the existence of the larvæ is not available and they consequently perish. Cold and extreme wetness are equally inimical to the development of the larvæ, and so it happens that in such countries as those mentioned, spring and autumn are the seasons when flies are most prevalent. In this connection it is noteworthy that adult flies appear to suffer severely from thirst during periods of unusually hot weather. Major Austen noted that during a *khamsin* flies " apparently maddened by thirst displayed a restless and altogether abnormal

activity, crawling, evidently in search of refreshment, over the faces of would-be sleepers until at least 11 p.m." This was often noticed by Lieut.-Colonel Sewell who saw flies on similar occasions drinking greedily from water standing in canvas basins and buckets. At such times the thirst of flies may be used to their undoing, by supplying them with poisoned drink, which they devour greedily, with fatal results.

Several experiments have been recorded relating to the distance that flies travel. At Postwick, in Norfolk, in 1910, marked flies were found within forty-eight hours at distances ranging from 300 to 1,700 yards, and, in an experiment made at Ottawa, 600 and 700 yards from the place at which they were set free.

There is also evidence that, over water, house-flies may be carried by the wind to a distance of 5 or 6 miles, and in one case a flight of 13 miles over land has been recorded.

These experiments, however, appear to have little value as regards field conditions, in view of the fact often observed that flies habitually travel all day on the backs and helmets of men on the march, and also perch on the top of loads carried by transport animals. In this way there is no doubt that flies travel from camp to camp at the same rate of progress as the troops.

Preventive Methods employed against Flies during the War.

The probability of a plague of flies in Flanders was foreseen by the Director-General, Army Medical Service, War Office, who appointed a committee in April 1915 to investigate and report on the best methods to employ for the prevention of flies. The committee consisted of Professor Robert Newstead, (Liverpool University), Captain E. E. Austen (British Museum), and Mr. Rupert W. Jack (Government Entomologist, Southern Rhodesia). After examining conditions on the spot they made an interim report. In the meantime a circular memorandum was issued by the Director-General, Medical Services in France, entitled "The abolition of flies in camps, billets and hospitals." This pamphlet, after pointing out the danger of disease being carried by flies, enumerated the methods recommended for their destruction. It emphasized the fact that, while house-flies will breed in human excreta, garbage and other organic refuse, 90 per cent. of such flies breed in horse manure, and it was therefore in horse manure that they could best be attacked. Incineration was recommended as the best method of dealing with horse manure,

but where this was impracticable it might be treated by the method known as "close packing." The removal of old manure heaps from the vicinity of billets was advocated and the picketing of horses as far away as possible from billets, dining-rooms, and kitchens. Incineration of human excreta and, where that was not possible, deep trenches with fly-proofed seats were recommended. Shallow trench latrines were to be used only in exceptional circumstances, and then were to be constantly supervised to ensure that the excreta were kept covered with earth.

It was also directed that garbage was to be burnt, or where burning was impracticable, buried in a deep trench, and carcases were to be buried. The keeping of pigs in the close proximity of standing camps was prohibited. General cleanliness and the protection of food from flies were enjoined. Various methods were recommended for the destruction of the adult fly, such as "balloon" fly-traps, papers, wires, tapes, strings or other material covered with a sticky substance made by heating together resin and castor-oil, leather fly-flappers, and the spraying interiors of kitchens and mess-rooms with cresol emulsion.*

Two poisons were also described: formalin (1 in 80), with the addition of a little sugar or honey, for indoor use, and for outdoor use sodium arsenite, a solution of which was to be sprayed over such places as manure heaps and the surrounding vegetation; or leafy branches were to be dipped in solution and hung up over latrines and other places which attracted flies.

This memorandum indicated generally the methods employed for the destruction of flies in France, and with more of less important modifications in the other theatres of war. The various detailed measures were designed for two purposes, one for the destruction of the eggs, larvæ and pupa, and the other for the destruction of the adult fly.

Measures designed to destroy Eggs, Larvæ and Pupæ.

Horse manure was the most favourable breeding ground for flies, but the problem of its disposal presented many difficulties. No one method was satisfactory under all conditions of locality and climate. In the circular memorandum quoted above incineration was indicated as the best method, and where that was impracticable, "close packing." Incineration was

* Cresol 1 volume, kerosine 20 volumes; made up to 100 volumes by the addition of water. Five volumes of formalin may be added with advantage.

the ideal method of disposing of manure, and it was often possible to carry it out in dry weather, and in circumstances where litter was being issued. But in wet weather, when no litter was issued and in camps with a large proportion of horses, it sometimes became impossible to incinerate effectively. Incineration, however, should always be carried out wherever possible in the field, and the best form of incinerator was one of the closed type. Burning was facilitated considerably by previously drying the manure in the sun. The method was to mark out three areas; each area in turn was used to receive a day's supply of manure, which was thoroughly broken up and raked out into a thin, even layer. After three days' drying the manure was collected and burnt, either in an incinerator or in heaps or windrows. This method proved very satisfactory in a hot, dry climate, but careful supervision was necessary to ensure that the system was scrupulously followed, otherwise breeding was sure to take place. A modification of this system of spreading was employed in Egypt and Palestine, where manure was spread on the desert sand in order to make roads. Here, again, the success of the method depended entirely on the absence of lumps and the even spreading of the manure, so that rapid drying could take place. To attain this end it was found advantageous to rake over the manure again on the day on which it was spread out and on the two following days.

Under conditions in which incineration was not feasible close packing was found effective. This method was described in 1915 by Lieut.-Colonel S. A. Monckton Copeman. While experimenting with certain substances which were likely to prove serviceable as larvicides, he found that his control larvæ, which were placed in gauze cages in an untreated heap of manure, were dead and shrivelled after twenty-four hours. This unexpected result he attributed to the heat generated by the process of fermentation in the newly made manure heaps. On continuing his observations he found that the temperatures developed during fermentation largely depended on the manner in which the manure was stacked during the building of the heap, and where the heaps had been properly constructed and pressed down no eggs, pupæ nor larvæ could be found.

In order to arrive at an accurate estimation of the value of this method of treatment of horse manure it was essential to obtain experimental information as to the minimum temperature, exposure to which for a limited period was incompatible with continued existence of the larvæ of the fly. At Colonel

Monckton Copeman's request, Professor F. M. Howlett undertook an experimental investigation of the subject and reported that maggots were quickly killed by either dry or wet heat at any temperature above 46° C. (114·8° F.). He added that it was improbable that they could live long at a temperature over 41° C. (about 106° F.). The results of his experiments carried out at different temperatures were as follows :—

Temperatures to which exposed. (Degrees Centigrade.)	Period of Exposure which proved fatal to Fly Larvæ (in minutes).	
	Dry.	Wet.
50	2½	¾
48–49	8	2
46–47	21	2½
44–45	180	7
42–43	—	12½

Observations on the temperature attained in fermenting manure heaps were made, with the result that it was found that the temperature 4 in. below the surface ranged from about 65° to 75° C. for the first six days of fermentation, a degree of heat amply sufficient to kill all larvæ.

Almost simultaneously with the communication of the preliminary report of these results to the Congress of the Royal Sanitary Institute at Brighton on 2nd September, 1915, a paper was published in France by M. Roux, Director of the Pasteur Institute in Paris, on behalf of Dr. E. Roubaud. The latter stated that fermentation, after barely twenty-four hours, definitely prevented flies depositing their eggs in the manure. Fermentation was delayed by such antiseptics as borax, cresol and iron salts, and these chemicals therefore did harm by prolonging the period of infestation. Larvæ migrated from a manure heap in the first six days, and anti-fly measures ought therefore to be undertaken within five days of the removal of the manure from the stable. After the manure had been heaped for a day the temperature at the centre of the heap had risen to between 70° and 90° C. This heat might therefore be used to kill the larvae, which perished rapidly when exposed to a temperature of 50° C. The easiest way to effect this was to bury the new manure in a hole in the old manure heap, covering it with a layer of hot manure at least 20 cm. thick. In four or five hours the new manure was found to be free of eggs and larvæ.

The method of close packing was described in the circular memorandum cited above. It was essential that the manure should be stacked very tightly and that the surface of the stack should everywhere be beaten down as firmly and smoothly as possible. A convenient size for a close packed manure heap was about 500 cub. ft. (10 ft. square and 5 ft. high). The sides should slope slightly inwards and upwards. The ground on which the heap was to be placed should be thoroughly treated with mineral oil used for preserving wood, or one gallon of the oil should be mixed with about 7 cub. ft. of pulverized earth, and the mixture spread on the ground and beaten flat. This quantity was sufficient for about 100 sq. ft. of ground. The treated area should extend about 3 to 4 ft. beyond the limits of the manure heap to prevent migration of any larvæ which might possibly breed in isolated portions of the manure heap.

Fresh manure was carried to the prepared site and each load as it was deposited was piled compactly in a regular block, having regard to the final shape of the manure heap, and well battered down with spades; if the weather was dry the heap had to be sprinkled with water. The exposed sides were finally firmly beaten flat and smoothed over with a spade. The top of the heap was similarly dealt with and the tightness and smoothness of the surface could be improved by laying upon it boards weighted with stones. This thorough compression at all stages in the formation of the stack was absolutely essential to success. As an additional precaution the exposed surfaces of the manure heap might be sprayed each evening with the cresol-kerosine solution mentioned above.

Doubts have been expressed as to whether this method would be suitable in hot countries, but in one instance, at least, in Egypt it was employed with great success. Captain J. Davidson, R.A.M.C., described the disposal of the manure of a large camp at Suez by close packing. Two areas, each measuring 25 yards by 10 yards, situated 2,000 yards from the camp, were staked out. All manure and burnt refuse from the incinerators were hauled to these areas, and the areas were used on alternate days. On an average there were 80 wagon-loads daily, and a gang of 20 Egyptian labourers was employed in raking the manure and refuse level, picking out tins and burning paper, sacking and other refuse.

The day's collection of manure was drenched with a mixture of crude tar oil and soft soap and water at the rate of one gallon per square yard, watering cans being used for the purpose.

The heap was then covered with sacking, but later this was not found necessary and was discontinued. As the heaps rapidly increased in size, the wagons with their loads were hauled over the dump and this helped to pack it tight. After about four weeks the dumps were 5 ft. high, and new ones were commenced. At first hordes of flies came on the loads of manure from the camp, where extensive fly-breeding was going on. To get rid of these a solution of 1 per cent. sodium arsenite in water, sweetened with 12 per cent. glycerine and 5 per cent. sugar, was placed in old tins round the manure heaps. The flies collected in masses and were killed in enormous numbers, and at the end of a few days hardly any remained, the treatment of the manure preventing further breeding.

In ordinary domestic manure heaps to which additions were constantly being made fly breeding was difficult to control, but a great reduction in the number of flies hatching out could be made by collecting and destroying the eggs and larvæ by the method employed by Captain P. J. Marett, R.A.M.C., in camps and billets at Rouen. Flies when seen to be ovipositing were left undisturbed and the spot was marked. Later the clusters of eggs were discovered and burnt. Larvæ were caught in traps during their migration to moist, cool spots suitable for pupation. The migration took place at night, and the larvæ made their way to the earth or the straw on which the manure was placed, or to the old and cool portions of the heap. The traps were made of square ration tins with slits in all four sides at a level of about 2 in. from the bottom; the slits were kept open by means of a pebble placed inside, so that the upper edge overhung the lower; the tins were then filled with about four inches of sand or chaff and were embedded in the manure so that the slits were on a level with the surface of the manure. On wet nights the tops of the tins were covered over. In one such trap over 5,000 larvæ have been caught in a night.

Numerous chemical substances have been advocated at one time or another for preventing the hatching out of adult flies. Most of them proved unsatisfactory either on account of their ineffectiveness, expensiveness, or their poisonous properties. The only substances which proved satisfactory during the war were cresol (5 per cent. solution) and borax (1 lb. to 5 gallons of water). Either of these solutions applied by means of a watering can to the manure in adequate quantities prevented hatching out of adult flies. But the method was obviously

a very expensive one, and in ordinary circumstances the desired effect could be produced more certainly by either incineration or close packing.

The methods of disposing of human excreta in the field by shallow or deep trenches or by the bucket system followed by incineration or burial favoured the breeding of flies in different degrees.

Disposal in shallow trenches was the recognized method in Field Service Regulations before the war, but it was soon discarded, partly owing to the amount of ground taken up and partly owing to the fact that it provided an excellent breeding ground for flies. Larvæ hatched out in the excreta easily made their way to the surface through the thin layer of earth above them. As mentioned above, flies can emerge through 6 ft. of loose, dry sand.

Deep trenches, covered with fly-proof seats, were much used in France and were found satisfactory with proper supervision. In Egypt, however, where this system was officially recommended and given a fair trial, it was eventually discarded as extensive fly breeding was found to go on in a large number of deep trenches, in spite of all precautions taken to make them fly-proof. Major Austen caught 708 flies in fifteen minutes in one latrine of five seats. In another case he found 300 newly hatched flies beneath 2 sq. ft. of sacking spread over a filled-in trench. He also caught 1,217 flies in one five-seated box latrine in seventeen days by means of four lengths of hoop iron smeared with a mixture of resin and castor-oil, and in a second similar experiment lasting six days 2,013 flies were caught. The efficacy of various chemicals in preventing flies from entering the latrines was tested, but none proved entirely effective, and in the large quantities required their continued use was impracticable. The following were tried and are placed in order of their efficiency: Cresol, 1 pint per seat, diluted ten times; "C" solution, a mixture of creosote oil and light oil, in the same quantity and dilution; heavy oil, 1 pint per seat, undiluted; fumes produced by spraying 1 oz. of "C" solution on 1 oz. of bleaching powder per seat. Chlorine and sulphur dioxide gases proved ineffective.

In order to prevent flies emerging from deep latrine trenches after the latter were filled in, a system devised by Major E. E. Austen was employed to trap the newly hatched flies as they made their way to the surface of the soil. A sheet of sacking or hessian was spread over the trench and for a distance of 18 in. beyond it on all sides. The edges of this sheet were turned

down into a small trench 6 in. deep filled with a mixture of sand and cresol, tightly packed. The whole was then covered over with 4 in. of earth. The flies as they emerged from the pupal cases and sought the air were thus trapped and perished beneath the sacking.

The efficiency of this method was investigated in the field by Major W. F. Corfield. He carried out four different experiments at different times and in different soils.

In the first experiment three pits were dug in a clayey black soil. Each pit was 2 ft. long, 1 ft. broad and 3 ft. deep. Human fæces were placed in the bottom of the pits and exposed to flies for three days, after which the pits were filled and sealed with a single layer of sand-bags, split open and turned down beyond the margins of the pit in the usual way. The sand-bags were freely sprinkled, one with 10 per cent. solution of cresol, one with crude oil, and one with "C" solution. A layer of about 6 in. of soil was spread over the three pits. After five weeks the pits were opened, with disappointing results. Many empty pupæ cases were found, but practically no dead flies.

The second experiment was similar, with the exception that the sand-bags were soaked in the fluids instead of being sprinkled and a second seal of hessian was stretched over the sacking. But the results were similar. The pupæ cases were found collected at the corners and sides of the pits, showing that the larvæ had avoided the deterrents by making for the edges, and the flies had made their way round the edges of the seals.

In the third experiment the three pits were dug in hard caked sand with an admixture of clay. The pits were sealed with hessian. The hessian over No. 1 pit was left plain, that over No. 2 was soaked in crude oil, and that over No. 3 in "C" solution. Over each pit a bivouac mosquito net was erected with due precautions to prevent the escape of flies. A few flies appeared in the nets over pits No. 1 and No. 2, the first after six days, but none in No. 3.

When the pits were opened thousands of dead flies and thousands of pupæ cases were under the hessian in No. 1 pit. In No. 2 pit it was impossible to distinguish any large number of flies or pupæ in the sticky mass of oil and earth. No flies had escaped from No. 3 pit, and under the hessian only one fly (*Sarcophaga*) was found, but the earth, particularly that at the edges of the pit, was full of dead larvæ, which had evidently come to the surface to pupate and been killed there by the "C" solution.

In the fourth experiment three pits were dug in a similar soil to that of the last experiment. The first pit was sealed with plain hessian but the earth was stamped down as firmly as possible at the edges. The second was sealed with hessian soaked in " C " solution, and the third was sealed, not with hessian, but with six inches of mud, plastered on in two layers, the second layer about twenty-four hours after the first had dried. Seven days later there were some flies in the nets over pits No. 1 and No. 2 and two flies in that over No. 3. Next day the flies in Nos. 1 and 2 had increased considerably, and in No. 3 there were six flies. When the pits were opened the conditions in Nos. 1 and 2 were much the same as those in the previous experiment, while in pit No. 3, sealed with mud only, where no more flies had come to the surface after the second day, innumerable dead flies and pupæ were found in and below the hard mud seal.

It was consequently concluded from these experiments that in the summer in Palestine flies will hatch out within a week. In a latrine or refuse pit to which flies have had access, the large majority of fly eggs will hatch out within a fortnight, but flies will continue to be hatched out for another week. By the end of three weeks all flies will have been hatched out. It was also demonstrated that to seal refuse or latrine pits with sacking soaked or sprinkled with any sort of fly deterrent was useless, the effect of using such deterrent being to drive the maggots to the edges of the sacking, beyond which the flies will readily escape, and that if hessian or similar close-mesh material were used, it must cover an area beyond the original pit ; 6 in., the distance usually prescribed, was not sufficient. Finally, the simple expedient of plastering over the deep trench pit with well worked up mud, 6 in. thick and allowed to dry in layers, extending well beyond the pit margin, was as efficient as hessian or similar material.

These conclusions agreed with the practical experience of sanitary officers, who found that in camps where refuse had been buried in pits sealed with sacking or hessian, flies were plentiful, and that the flies had escaped from the pits, so that the use of that method, besides being ineffectual, was expensive and required a considerable amount of hessian.

Another objection to the use of deep trenches in Egypt was that owing to the looseness of the soil the sides of the trench had to be revetted with sand-bags, and this added to the cost of the system.

In Macedonia, however, the deep trench system appears to have been in partial use until the end of the campaign.

The bucket system combined with incineration or burial proved satisfactory and was eventually employed on all fronts whenever the situation permitted. An attempt was even made in Palestine to provide the troops with a portable sanitary equipment capable of being carried on a camel. This consisted of a nest of small buckets and a portable incinerator devised by Lieut.-Colonel Lelean. In practice, however, the number of buckets which could be carried by the " sanitary camel " was not sufficient for a battalion.

Where latrine buckets were not available, empty cresol and oil drums proved useful substitutes. In either case a fly-proof seat with a self-closing lid was used, and the seat usually took the form of a light frame fixed directly on to the rim of the bucket. In order to prevent flies finding their way into the bucket through any interstice between the bucket and the frame, it was the custom in Palestine to have a curtain of canvas attached to the lower side of the seat and fastened with a rope round the bucket.

The best method of disposing of the contents was by incineration, and no great difficulty was experienced in carrying this out except during a rapid advance and in very wet weather. In Palestine no fuel was issued for incineration, but waste and broken tibbin and camp litter were in most cases found sufficient to keep the incinerators burning. Almost any form of incinerator acted well, but the best was some form of closed incinerator, circular in preference to square in shape. In any case it was essential to ensure scrupulous cleanliness in and around the sanitary area, otherwise fly breeding took place, as larvæ were frequently found in fragments of organic matter beneath an incinerator and in its neighbourhood.

Another spot where breeding inevitably took place was in the pit which some units dug near the incinerator for ashes and old tins. Some of the material that found its way into these pits had not passed through the incinerator, and the pits soon became fly nurseries. It should be the rule never to allow any form of pit to be dug near the incinerator. The ashes from the incinerator should be piled instead in a heap open to easy inspection, and tins should be sorted out and piled separately.

Burial of the contents of latrine pails was open to the same objection as the deep latrine trenches, but one system of burial was possibly free from objection. A deep pit was dug, the deeper the better provided that the subsoil water was not

reached. The top of the pit was covered over with planks and earth. In the middle of the cover an opening about 2 ft. square was cut in the planks, and into this opening was fixed a box with a well-fitting flanged lid. Into this pit all the latrine buckets of the unit were emptied, no earth or disinfectant being added. The pit thus became a kind of septic tank, and liquefying processes commenced, with the result that any larvæ that might find themselves in the pit were soon drowned in the liquid. No unpleasant smell was detected near the pit, especially if the square opening was kept covered with a piece of sacking soaked in crude oil. Such a pit could not be used when there was a danger of contaminating a water supply, but otherwise the method seemed safe, simple, and effective.

In disposing of camp refuse, incineration was universally adopted on all fronts. Burial invariably led to fly breeding.

The carcases of dead animals were the breeding place of blue-bottles (*Calliphora*), green-bottles (*Lucilia*), and grey flesh flies (*Sarcophaga*), which although not so dangerous to health as house-flies, become a source of great annoyance.

Carcases were best disposed of by burning or partial burning, where possible, otherwise by burial. In the advance through the desert of Sinai dead camels, horses and mules were dealt with as follows: At the selected burial ground a large pit about 6 ft. deep was dug, into which were put some old sacking, tibbin, firewood, and other material saturated with oil. Two or three stout iron bars were placed across the pit. The carcases were disembowelled, the cavity being filled with tibbin or old sacking saturated with oil. The legs were cut off and the prepared carcase placed over the pit on the iron rails. Oil was then poured over it and the whole set on fire. Gradually the remains of the carcase fell into the pit which, when the fire was spent, was filled in.

Experiments were carried out at Cambridge in 1915 by Foreman and Graham Smith with the object of finding a chemical combination which would arrest putrefaction and fly-breeding in carcases. The substance eventually recommended was the " C " solution. It was found very effective in suspending putrefaction and arresting fly-breeding in carcases, and it was used for this purpose in France and elsewhere. It did not, however, come into general favour owing to certain disadvantages, among which were its inflammability, bulkiness, and expensiveness, while it was also found to be very irritating to the skin and eyes.

Measures designed to destroy Adult Flies.

The various methods employed for destroying the adult flies were traps, poisons, sprays and fumes, and direct action by means of flame and "fly-flaps" or "swatters."

A large trap intended for outdoor use was devised by Lieut.-Colonel Andrew Balfour. Three forms were designed—a large

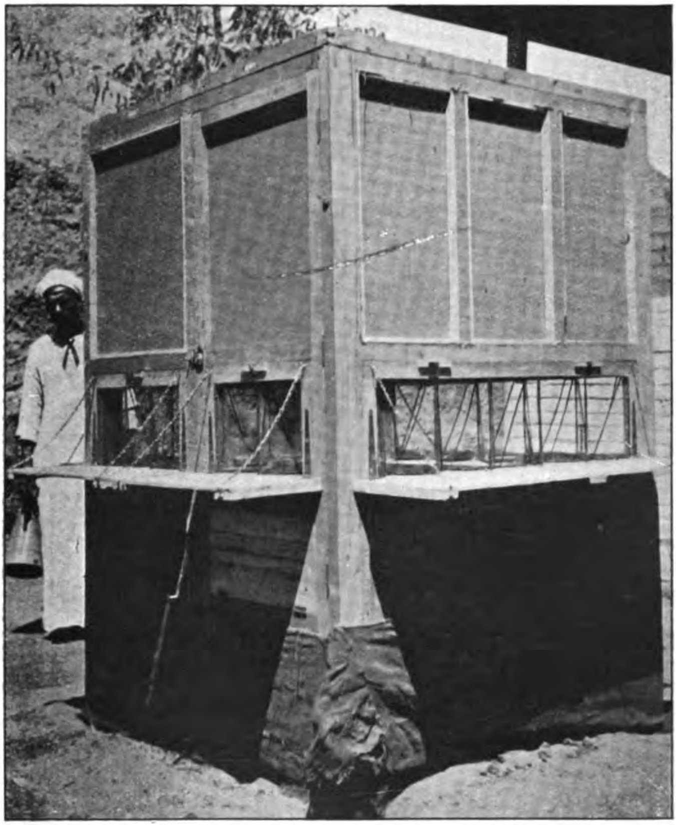


Fig. 1.—Balfour fly trap. Large form in action.

form (Fig. 1) built of wood, glass and wire gauze, an intermediate form made of wood, canvas, glass and wire gauze (Fig. 2), and a small form made of wood, canvas and wire gauze (Fig. 3). The principles on which the three forms of trap depended were the same. The flies were attracted by

baits of various kinds, such as milk, lentil paste, cheese, tea-leaves, jam, chicken entrails and fish refuse, and entered by a narrow slit in the side. Once inside they seldom found their way out, and could then be killed by fumigation. The trap was rendered more attractive by being placed in a sunny spot where, the roof being made of glass or canvas, it was well lighted and warmed by the sun. In cold weather the warming could be done by a small charcoal stove.

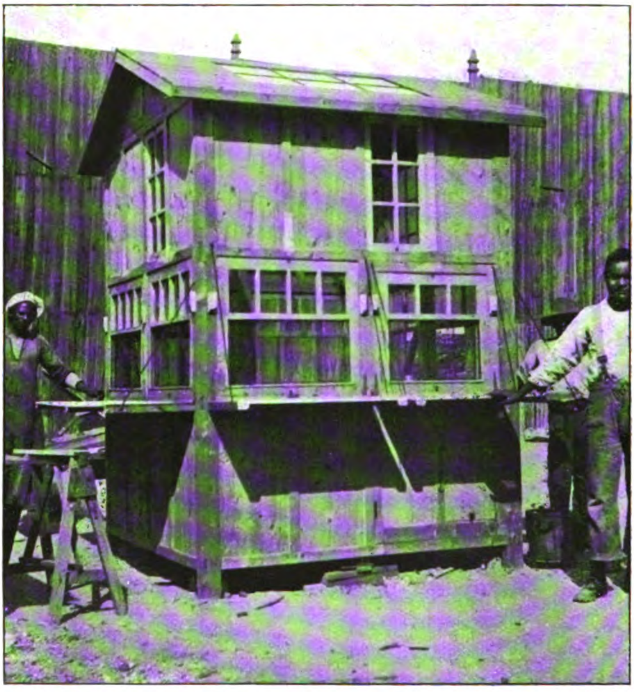


Fig. 2.—Balfour fly trap. Intermediate form in action.

An essential part of these traps was a board or platform in front of the slits to facilitate flies landing on entering the trap.

The small form, being the simplest, cheapest and most portable, was the most suitable for the field. It could be made of any size or shape, but one cubical in shape with sides 3 ft. square was a convenient size. It consisted of a wooden framework standing on a smooth board, which projected 4 in. beyond the trap on each side. The upper half of the trap was made

of canvas stretched tightly over the framework, while the lower half of the sides and the top were made of wire gauze. The lower edge of the gauze did not reach to the base-board, but its free edge was turned inwards and upwards forming a flange 2 or 3 in. wide and leaving a narrow slit, just large enough for a blue bottle to crawl through. A door should be made in one side for the insertion of the simple apparatus for fumigation and canvas flaps might be added, as in the illustration, in order to give protection from the wind on a breezy day.

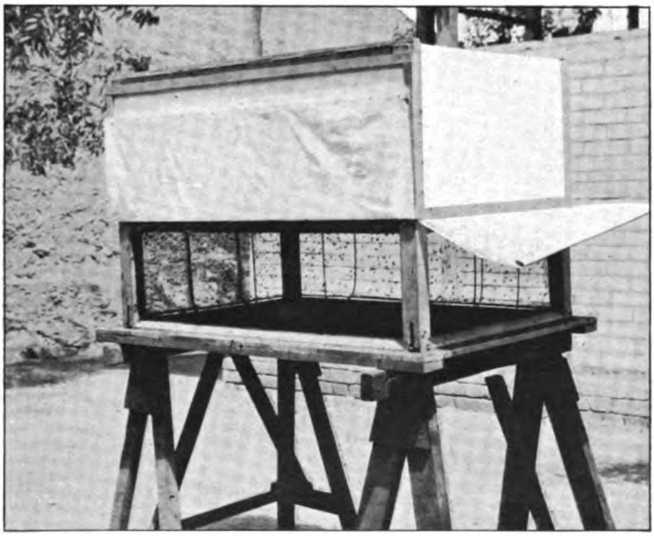


Fig. 3.—Balfour fly trap. Small form in action showing calico shutter partly lowered. Note flies on wire mesh.

Traps of this description were much used in hospitals and base camps in Egypt and proved effective. It was stated that as many as 10,000 flies had been caught in one such trap in two hours.

Of small traps for indoor use the " balloon " trap made of wire gauze was effective. It could be baited with any articles attractive to flies, and the entrapped flies could then be killed by dipping the whole trap into boiling water or placing it for a minute or two in a hot oven.

The Japanese clock-work trap, which was supplied to hospitals in Egypt, was very ingenious and effective, but it was too complicated and delicate for general use.

Sheets and ribands of paper sold under the name "tanglefoot" were in constant use. An essential for success was that the papers should remain still and not be moved by the wind. The sheets were more effective in the day-time and the ribands, hanging vertically downwards, at night.

The sticky substance could be made by heating together five parts of castor-oil and eight parts of powdered resin, stirring vigorously all the time. The mixture, while hot, was then spread thinly on glazed paper or on strips of iron such as were used for binding compressed fodder, or lengths of wire were dipped in it and suspended vertically.

The two poisons that were universally used in all war areas and found effective were formalin and sodium arsenite. A fly poison which was harmless to man was made by mixing one dessert-spoonful of formalin with a pint of water (1 in 80) to which had been added a dessert-spoonful of sugar or honey. It was found that formalin exposed to air soon became acid owing to the formation of formic acid and this repelled the flies. It was necessary therefore to add some carbonate to neutralize the formic acid, or lime water could be used instead of water in making the solution.

This poison was best employed by exposing it in saucers placed on tables in kitchens and mess-rooms where flies were wont to congregate. It appeared to be most effective early in the morning and in the absence of other forms of food. An island of bread should be placed in the saucer to afford a landing place for the flies.

Sodium arsenite had the disadvantage of being highly poisonous, but with due precautions it could be freely used and was the most effective poison employed during the war in some areas. A one per cent. solution in sweetened water was the form in which it was generally used, solution being aided by heat.

The salt was issued in 1 grm. tablets and each tablet was dissolved in 3½ oz. of water containing 12 per cent. of sugar or gur. This solution was in some localities used for spraying or sprinkling manure heaps and latrine trenches. It was first introduced in the campaign against German South-West Africa, where brushwood or palm-leaves were sprinkled with the solution and suspended in the neighbourhood of the latrines.* In Egypt and Palestine the method most commonly adopted for using this poison was the following: A cigarette tin was used

* See p. 346, Vol. I, of the General History of the Medical Services during the War.

as a reservoir, into which was dipped one or more wicks made of rag or lint. These wicks were passed through suitable holes made in the lid of the tin and projected 1 or 2 in. beyond the lid, which was replaced on the tin. The wicks kept moist by capillary attraction and the apparatus required no further attention for several days. Such tins were placed in mess tents and in bivouacs without any risk to human beings.

In Mesopotamia another form of apparatus for the use of arsenite of soda found favour. This consisted of a roughly made rectangular frame fixed vertically in the ground and supporting a roller, over which a piece of sacking like a roller-towel was suspended. The lower end of the towel dipped into a solution of 6 oz. of sodium arsenite in 3 gallons of water sweetened with 24 oz. of gur or sugar which was contained in a kerosine tin. This solution was sufficient for one trap for a fortnight. The towel was kept moist by rotating it at intervals. This trap was placed near latrines, garbage pits, manure heaps and slaughter yards, but at a distance from cookhouses, mess tents and water supply.

Sprays and fumes, although ineffective in the open, were found useful in killing flies in tents, huts and buildings, and they were used to the greatest advantage in the evening after the flies had settled down for the night.

The fluids most commonly employed were cresol (1 in 360) and Lefroy's fluid (1 in 40). The latter consists of pyrethrum powder 2 lb., methylated spirit 1 gallon, saffrol 1 gallon, and aniline 1 ounce. For use it is diluted with 40 volumes of water or preferably of soap solution : 10 c.c. of the undiluted solution is sufficient to spray 1,000 cub. ft. The solution was somewhat expensive and in practice it was found that flies were not killed unless the fluid came into actual contact with them. The cresol spray was found equally effective and cheaper and was always available.

In Macedonia a paraffin emulsion was tried by Captain J. Waterston, R.A.M.C., and found to be very efficacious. It was made of 1 gallon of paraffin with ¼ lb. of soap and ½ gallon of water. The undiluted emulsion proved fatal to flies almost instantly. Keating's powder (pyrethrum) burnt on a tin lid over a flame in a confined space was also poisonous to flies.

Flies, when seeking a resting place for the night, seem to prefer anything hanging vertically from the ceiling of a room or from the top of a tent. They cluster thickly on a hanging piece of cord or string and large numbers of them could be

destroyed at night by applying a torch of paper or of cotton-wool soaked in methylated spirit to such clusters. Or a saucer with a little petrol in it might be held under the cluster, when the flies, becoming stupefied, would fall into the liquid and perish.

In the Eastern theatres of war "swatters" were issued to the troops and proved of great value in reducing the number of flies in a small space such as a mess-room. The wire gauze variety caused most execution but the leather ones lasted longer.

For the protection of food from flies, fly-proofing of kitchens was not, as a rule, practicable on active service, but in several cases, especially in hospitals, this was carried out. Several units provided themselves with a fly-proof meat store. Some of these stores were completely underground and the entrance was closed by a door made of sacking or mosquito netting on a wooden frame.

Meat safes were issued to all units in Palestine and Macedonia, and muslin was also supplied for the purpose of covering food on the mess tables in these theatres of war and elsewhere. Ordinary fishing nets were used to exclude flies from hospitals, officers' messes and other places, in houses, huts, or marquees. It was found that flies would not pass through such nets when hung loosely over doors and windows. A mesh of $\frac{3}{4}$ in. was quite sufficient to deter flies from entering a room. One of the general hospitals in Alexandria suffered from a severe plague of flies in the wards until this simple device was adopted. After the windows had been covered with fishing nets the number of flies became very appreciably less in the wards.

Sandflies.

P. papatasii, and probably several other species, are the carriers of phlebotomus or sandfly fever, a disease which was very troublesome among the French troops at Cape Helles and caused much sickness in Egypt, Palestine, Macedonia, and Mesopotamia.

The fly is exceedingly minute and remarkably hairy. When at rest it holds its wings in a characteristic attitude which has been very aptly compared with that of a deer's ears. The adult fly lays its eggs in crevices in stone walls, in cracks in parapets of trenches and dugouts, and in heaps of stones, bricks, piles of rubble, and also in the surface of the soil. A certain amount of moisture is necessary for the development of the larvæ. The adult fly shelters in similar situations, in clods of earth, beds of streams, holes in trees, caves, and in dark corners of rooms. It passes the winter in a larval state, and

the fever, therefore, is only met with in summer. It shuns daylight and bites chiefly at night. In the day-time it might be found in dark corners, and a favourite place was behind the valence of marquees or between the covers of double-fly tents. In these situations sandflies were often found in enormous numbers, even when, owing to the absence of bites, their presence was not suspected. When disturbed they jump to one side, almost like a flea, a characteristic movement of the sandfly.

Towards evening the female flies sally forth on their blood quest, feeding principally in the gloaming and at dawn. They attack chiefly the wrists and ankles and can bite through thin socks and light clothing. The bites are extremely irritating, many persons feeling them more severely than mosquito bites. The irritation of the bites often persisted for two or three days.

Protection against sandflies under field conditions was almost impossible, and in badly infected areas 50 per cent. of the troops might develop the fever within a few weeks. Where the flies were numerous, large numbers could be killed by fumigating rooms and dugouts with sulphur or spraying with formalin or cresol. Tents were treated in the same way. Certain repellent ointments were useful, " vermijelli " proving one of the best, and various essential oils, especially oil of cassia, were effective as long as the scent lasted. In the absence of anything better paraffin would secure a few hours' immunity from annoyance. But the only real measure of protection was in the use of a mosquito net fine enough to keep out the minute flies. A net with a mesh of twenty-two holes to the linear inch was effective, but the insect would find its way inside a net that was not carefully tucked in under a mattress, and the smallest hole was certain to be discovered by the hungry fly.

BIBLIOGRAPHY.

Austen	The House-fly, its Life-history and Practical Measures for its Suppression.	British Museum (Natural History) Economic Series, No. 1a, London, 1920.
Balfour	Fly Traps for Camps, Hospital Precincts and Trench Areas.	Jl. of R.A.M.C., 1916, Vol. xxvii, p. 61.
Bishopp & Laake ..	The Dispersion of Flies by Flight.	Jl. of Economic Entomology, Concord N.H., 1919, Vol. xii, p. 210
Buxton	The Importance of the House-fly as a Carrier of *E. histolytica*.	Brit. Med. Jl., 1920, Vol. i, pp. 142, *et seq*.

BIBLIOGRAPHY—*cont.*

Copeman	Prevention of Fly-breeding in Horse Manure.	Lancet, 1916, Vol. i, pp. 1182–1184.
Copeman, Howlett & Merriman.	Further Reports (No. 4) on Flies as Carriers of Infection.	Reports to L.G.B on Public Health and Medical Subjects, New Series, No. 53, 1911.
Corfield	Some Experiments upon the Control of Fly-breeding Areas in Camps.	Jl. of R.A.M.C. 1919, Vol. xxxiii, p. 415.
Davidson	The Control of Flies in the Egyptian Campaign.	Bull. of Entomological Research. Vol. vii,i p. 297.
Foreman & Graham Smith.	Investigation on the Prevention of Nuisances arising from Flies and Putrefaction.	Jl. of Hyg., 1917-18, Vol. xvi, p. 109.
Hewitt	Further Reports (No. 3) on Flies as Carriers of Infection.	Reports to L.G.B. on Public Health and Medical Subjects, New Series, No. 66, 1912.
Ledingham ..	Dysentery and Enteric Disease in Mesopotamia from the Laboratory Standpoint.	Jl. of R.A.M.C.,1920, Vol. xxxiv, pp.189 and 306.
Marett	Fly Prevention Measures ..	Jl. of R.A.M.C.,1915 Vol. xxv, p. 456.
McDonnell & Eastwood.	A Note on the Mode of Existence of Flies during Winter.	Jl.of R.A.M.C., 1917, Vol. xxix, p. 98.
Roubaud	The Production and Self-destruction of Domestic Flies in Horse Manure.	Compt. Rend. Acad. des Sci. 1915, Vol. clx, p. 325, also Jl. of R.A.M.C. 1916, Vol. xxvi, p. 107.
Taylor	The Rôle of the Fly as a Carrier of Bacillary Dysentery in the Salonika Command.	M.R.C. Special Report Series, No. 40. Lond., 1919, p. 68.
Thomson, D., & Thomson, J. G.	Protozoological Researches, including Investigations on the Sand in Egypt, undertaken to elucidate the Mode of Spread of Amœbic Dysentery and the Flagellate Diarrhœas; with conclusions regarding the Sanitary Measures necessary to prevent these Diseases.	Jl. of R.A.M.C.,1916, Vol. xxvii, p. 1.
Wenyon & Connor..	The Carriage of Cysts of *E. histolytica* and other Intestinal Protozoa and Eggs of Parasitic Worms by House-flies.	Jl. of R.A.M.C.,1916. Vol. xxviii, pp.522.

CHAPTER XII.

PREVENTION OF INFESTATION BY LICE.

THE important part played by lice in the dissemination of disease was clearly demonstrated during the war. It was known before the war that lice were the vectors of typhus fever and relapsing fever, but researches carried out during the operations on the Western front by British and American medical officers and by the Trench Fever Committee in England proved that lice are also the vectors of trench fever. The importance of these researches from a military point of view may be judged from a study of the admissions to certain casualty clearing stations. A careful examination of the figures of the casualty clearing stations of the Second Army in 1917 showed that out of a total of 106,267 admissions at least 20,000 were due to trench fever.

These three diseases—typhus, relapsing fever, and trench fever—may be conveyed to healthy persons by lice that are crushed upon the excoriated skin after having fed upon persons suffering from the diseases; moreover, in typhus and trench fever the excreta of the lice carry the infection and lice may consequently transmit the diseases by their excretal matter being rubbed into abrasions on the skin. Possibly, too, the bites of lice may cause a sufficient lesion to enable the virus to enter the body.

Lice feeding on a typhus case from the third to the tenth day of the attack are capable of transmitting infection seven to ten days later, and probably remain infective for a considerable period after this. Lice that have fed on the blood of patients suffering from relapsing fever may transmit the disease some hours after they have fed, but they do so chiefly for a period of three to fifteen days after becoming contaminated.

By causing irritation and scratching, lice also play a part in the development of inflammatory conditions of the skin. There were more than 10,000 admissions for these conditions to the casualty clearing stations above mentioned. Further, the loss of sleep consequent on the presence of lice impaired the vitality, produced mental weariness in the soldier, and diminished his value as a fighting man. The importance of lice prevention amongst troops in the field therefore cannot be over-estimated.

While it is the body-louse, *Pediculus corporis*, which is the transmitter of the infective fevers, skin conditions are caused

by the crab-louse, *Phthirus pubis*. The first symptom of the presence of the latter is pruritus, varying in intensity in different individuals. The pustular eruption and eczematous inflammation that may accompany their presence are mainly due to scratching. Febrile symptoms may, however, also be caused by crab-lice, but from the military point of view the chief importance of crab-lice lies in the skin lesions produced by scratching.

Biology of Lice.

Pediculus corporis chiefly infests the clothing, but it has repeatedly been found to lay its eggs on the body hair, a fact which is commonly overlooked but which explains why men may re-infest their clothes after these have had the lice in them destroyed.

The shirt is preferred, but in many cases most eggs are found at the fork of the trousers and under the seams. This is because the trousers are worn consecutively for a much longer period than the shirt. In order of importance, the areas most favoured for egg-laying are the fork of the trousers, the armpits, and the triangles at the tail of the shirt.

A female lays any number up to 300 eggs, at the rate of 8 to 12 a day under favourable conditions on man. It does not oviposit at 20° C. or under. The eggs hatch after a variable time according to the temperature at which they are maintained: in six to eight days at 32–35° C., in seven to fourteen days at 30° C., and in sixteen days at 25° C. Hatching, however, may be considerably delayed, sometimes for thirty days in cold weather, in eggs attached to clothing that is removed at night. In insects maintained continuously on man the life-cycle, egg-to-egg period, is completed in sixteen days. The eggs may survive for an undetermined number of days at 0° C. or under, and for three weeks at 10° C. They have been seen to hatch after thirty-five days and develop normally when kept warm and cool alternately for twenty-four hour periods. A knowledge of the influence of temperature upon hatching of nits is of practical importance in relation to the storage of clothing as a means of destruction of lice, for by storing clothes in a sufficiently warm place the required storage period can be greatly curtailed. For the same reason it should be noted that the larval and adult stages, when starved, live longer at lower temperatures. Experimental records show that they may live twelve hours at 40° C., three days at 36° C., five days at 30° C., six days at 20° C., seven days at 15–18° C., nine days at

10–12° C., and up to ten days at 5° C. The active stages may survive seven days' exposure at −12° C. When immersed in water nits survive ninety-six hours at 10° C., while the active stages may survive sixty hours' immersion.

As a result of many experiments carried out in France, Lieutenant Peacock found that the longest period during which lice survived separation from the human body was nearly nine days.

The following results were noted :—

On an infested shirt, newly discarded and exposed to the open, during which time the temperature varied between 40° F. and 45° F., two days being raw and wet, lice lived as long as five days.

On infested shirts, taken singly and stored in large army biscuit tins or in brown paper parcels, they may live about seven days ; on shirts stored in bulk, eight days.

Placed upon freshly dug soil, they lived seven days. On a piece of shirt which was placed upon soil in a large biscuit tin they lived eight days. Dry soil to the depth of 2 in. was placed on the bottom of a box 2 ft. by 1½ ft. by 1½ ft. The soil was covered with pieces of wood imitating in miniature the conditions of a dugout. An infested shirt was then placed in the box. The lice congregated upon the uppermost part of the shirt and remained there alive for eight days.

A constant feature is the moribund condition into which the insects sink after two days' separation from the body. This condition lasts till death. On taking a moribund louse and placing it on the arm there is evinced a quick response. The insect begins to take a distinct interest in life and shows it by perambulation and feeding. In connection with this " warmth test " it is important to note that five minutes may be required before there are signs of activity on the part of the louse.

The maximum time during which eggs may remain dormant away from the body has been found by Warburton to be about forty days. This was under laboratory conditions in England, where the temperature fell at times below freezing point. Similar experiments were carried out in France, shirts holding eggs being exposed to weather conditions. Samples taken from one shirt which had been exposed for eight days hatched after four or five days' incubation on the body. During the time of exposure the temperature fell twice to freezing point, and two days were raw and wet. Samples taken from a shirt exposed thirteen days did not hatch after twenty-eight days' incubation.

In applying this knowledge the important fact is that eggs on the clothing, particularly the outer garments, if not treated regularly by ironing or disinfection, are a possible source of infestation for as long as a month after they have been deposited. Also, the removal of the clothing from the body for a few days in order to kill the eggs and lice by exposure is not a practicable scheme.

The parasite's powers of endurance appear to be small. The examples cited, however, show that these powers are by no means inconsiderable.

The louse, therefore, is a parasite which is entirely dependent upon man's blood for sustenance and man's body and clothing for prolonged life and reproduction.

A common source of error in judging of the effects of insecticides or of heat or immersion is that the lice may appear to be dead while in reality still alive and able to recover after one to twenty-four hours. In practice it is best to rely upon the unequivocal signs of death. In nits this is shown by the complete collapse of the shell and the contraction of the contents into a small space, and the change to a whitish colour when coagulated or brownish when dry-heated. In the adult louse death is indicated by its shrivelling, becoming brittle, and changing to a whitish colour when coagulated or a brown or black when dry-heated.

The biology of the *Pediculus capitis* is similar, any differences being merely racial. It lays fewer eggs and is shorter-lived when starved. The eggs are mostly laid on the hair bases close to the scalp, but they may occur on any hairy part of the body.

Phthirus pubis lives continuously upon the skin, favouring the pubic and peri-anal region, but also extending upwards over the abdomen and chest and invading the axillæ or downwards over the thighs. At times it is found all over the body with the exception of the feet, hands, neck, and head. On rare occasions it is found on the eyelashes, the nits giving them a dusty appearance, and on the eyebrows, beard, and hair at the margins of the scalp. The active stages, when occurring on the eyelashes at the hair bases on the upper lids only, may escape notice. The nits are laid at the bases of the hairs and the insects usually cling to the hairs, keeping close to the skin. In contrast with the habits of the *Pediculus*, which feeds periodically when the host is at rest, *Phthirus* feeds almost continuously throughout its active life and during this period scarcely wanders farther than a couple of inches from the spot where it was hatched. The female lays 26 eggs or more in her lifetime. The eggs hatch in seven or eight days, and the life-cycle is completed in twenty-two to twenty-seven days. The active stages of *Phthirus* die rapidly when removed from man; very few survive twenty-four hours at 16–20° C., and all are dead in forty hours, be the atmosphere dry or moist. This, again, is in marked contrast to the biology of the *Pediculus*.

Mode of Infestation.

Infestation with *Pediculus* occurs mainly through contact and close association with verminous persons, from whom lice are shed or wander away. Their spread is, therefore, greatly favoured when men sleep close together. Infestation may occur indirectly through clothes, bedding, combs and brushes,

and other effects that have been used by lousy men. Much more rarely does infestation occur through stray lice that have been dropped from lousy clothes. Lice may fall from infested men when they scratch themselves or undress, and it has been shown that such lice may be carried some distance when infested men undress in a strong wind. Lice abandon the verminous dead and discarded verminous clothing.

Similarly, the high temperature of patients with fever is repellent to lice and they wander away in search of more congenial surroundings. In this lies the danger of approaching too closely lice-infested cases of typhus or relapsing fever without due precautions.

Infestation with *Phthirus* occurs mainly through coitus, but it may also result from close association, as occurs in scabies, the active stages being transmitted by contact; moreover, nit-bearing hairs are often shed and probably disseminate the parasite frequently either directly or indirectly. The active stages may also be transmitted indirectly through clothing, but this is less likely to occur than with *Pediculus*, because *Phthirus* clings much more closely to the body, is helpless on clothing, and is much shorter-lived when removed from man.

It is easy to understand from these facts how the troops first became infested. A few men harbouring lice, perhaps unconscious of it themselves, were quite sufficient to form a focus from which infestation rapidly spread owing to the communal life in barracks and tents. In the early days of the war, when tented camps were rapidly formed and men lived in the closest contact with one another, it was difficult to prevent the spread of infestation in this manner. In the United Kingdom everything possible was done to disinfest units by careful medical inspection, change of clothing, and bathing, but owing to the mobilization of large numbers of men and their hurried despatch overseas it was inevitable that many units were embarked with foci of infestation still present.

In order to obtain definite information as to what really constituted lousiness of the soldier, Lieutenant Peacock made a careful examination of units of a division in France, which had then seen six months of hard work at different parts of the line. He found that 95 per cent. of the men examined were infested and the average lousiness was twenty lice per man; five of the men in every hundred were found to have on them from 100 to 300 lice each. When clean shirts had been issued in the trenches, even at the end of two days they were again as highly infested as before; young lice had hatched

from eggs on the trousers and also adult lice had migrated to the shirt. Clean underclothing, after men had bathed, became infested from the outer clothing within half an hour. It was thought that men living in a bare trench would be more free from lice than men living in dugouts. They were, however, found to be equally infested. In the bare trench it was impossible to change clothing, and in the dugouts, where changes could be effected, the men lived in such close contact as to favour infestation. There was an impression that dugouts were swarming with lice, but Lieutenant Peacock did not find this to be the case and concluded that while lice might be present in a dugout these played a minor part in the harbouring and disseminating of the parasite. Except in the case where the men were very unclean, he did not find blankets to be heavily infested, the number of lice only amounting to an average of 0·8 per blanket examined. Blankets did not therefore seem to be of great importance as foci of dissemination, the main source of which was the soldier himself. Dissemination might possibly occur by three methods—accident, contact, and instinct on the part of the insect. In the first instance the ordinary actions of every-day life, dressing and undressing, may dislodge the insects from the inner clothing to the outer, or from the outer directly to the clothing of a comrade, or indirectly through blankets and kit. In the case of contact, transference may be effected during close proximity for a short time. The principal conditions of transference are the long periods of proximity, engendering warmth and consequent movement of the lice, as when men are compelled to sleep closely together. If the surroundings of the host be warm and comfortable lice are tempted to wander. In this way a bed may be infested by the host having left the bed before the louse commenced to wander back to him. But lice soon find the body of a host sleeping on infested bedding. The warmth of the bed is an incentive to wander and come in contact with the body, and in addition the insect is believed to scent the host. The instincts, however, of detecting and pursuing the host seem feeble.

Prevention of Lousiness.

The habits and life-history of lice indicated the lines along which measures for preventing them were directed. Thus the measures adopted during the war comprised :—

(1) The detection of men who were infested.
(2) The cleansing of the men by bathing.

(3) The disinfestation of all clothing and bedding in the possession of lice-infested men.
(4) Disinfestation of billets or other occupied buildings.

The relative importance of these measures was recognized from the commencement of the war. The early detection of lice-infested men was found to be essential if the spread of lice amongst a unit was to be prevented. As lice were present chiefly on the underclothing and service dress, few being detected in blankets or on the man himself, attention was concentrated upon frequent inspection of men to detect cases of lice infestation and upon thorough and systematic disinfestation of the men's kit, including all underclothing and service dress. When possible blankets were also disinfested, but if facilities were not sufficient to disinfest both clothing and blankets at one time, clothing was given the preference. It was found useless to disinfest blankets without at the same time disinfesting all underclothing and service dress. Similarly, it was useless to bathe and cleanse men without at the same time disinfesting all their clothing.

Inspection of Men for Lousiness.

The rules were to inspect all troops at least once a week, the inspection including the men's bodies and their clothing. The men were stripped for inspection, their clothing being rapidly removed immediately before the examination and turned inside out. The underclothes and outer garments were carefully examined, special attention being given to the shirt, the seams of the clothing and the fork of the trousers, as being the most likely places to harbour lice and nits. A large number of nits might often be present beneath the small piece of linen covering the rough seams at the fork. The kilt with its many folds was notorious for its liability to become infested.

Pediculus capitis had to be looked for at the occiput and sides of the head, above and behind the ears. In cases of slight infestation the nits were more readily detected than the active stages and they were best seen on dark hair; recently laid nits being found at the hair bases.

Phthirus was naturally looked for most frequently in the pubic region, next in the axillæ, and lastly about the eyelashes, where it but rarely occurred.

In the early days of the war, however, owing to the constant fighting and the rapid movement of troops, adequate routine medical inspection of healthy troops was an impossibility.

After the development of trench warfare there was little improvement for some time, as many units occupied the trenches for two to three weeks at a time, and many of the medical officers were as yet inexperienced. Even in the latter part of 1915 it was not uncommon to find 95 per cent. of the troops verminous after a twelve days' sojourn in the trenches.

Bathing.

Troops should have a bath and a change of underclothing once a week, but, like the medical inspection, it was not easy to arrange for this. Much, however, was attempted and a certain amount accomplished by capable and enthusiastic commanding and medical officers. Ground-sheets were used for improvising baths, and some battalions even carried large tarpaulins for the purpose. Advantage was also taken of any natural bathing facilities such as rivers or streams. Such efforts were, however, quite inadequate to deal with the problem as a whole, and as soon as possible more ambitious schemes were evolved. Divisional baths were formed by utilizing local resources, and the vats of breweries and dye-works proved inestimable as baths, while their buildings provided dressing and undressing rooms, and rooms for disinfesting, ironing, and mending of clothes. As an illustration of what was attempted, the arrangements made for the bathing of troops by the A.D.M.S. of the 4th Division early in the war are instructive.

On 15th November, 1914, a large linen factory on the banks of the Lys was chosen. It had large modern boilers, which heated the water for the bleaching vats, worked the machinery, provided steam for the drying rooms, and worked a dynamo for electric lighting. Rooms were used for the purposes of a bathing establishment as follows :—

Changing Room.—This was a large room 25 by 23 yards, with doors at each end for entrance and exit ; the stands for linen round the room were left for the convenience of soldiers undressing.

Bath-room.—This also was a large room with doors at each end and contained seven large vats, each holding fourteen men at one time ; six only were used in addition to two tanks for cresol solution. A store was formed in one corner for the issue of clean underclothing.

Ironing and Washing Room.—This room was 75 yards long and 15 yards wide ; it contained a number of long narrow tanks, which were kept filled with boiling water for washing clothes. Portions of this room were reserved for ironing and mending.

Drying Rooms.—These were two in number and fitted with movable horizontal poles on which the wet clothes were placed and dried by hot air, which raised the temperature of the room to 100° F.

Examining Room.—A small room was set aside for this purpose, where two men examined all clothes after treatment and so prevented the re-issue of any garments containing lice or ova.

Receiving Room.—This was a small room where clothes from the examining room were made up into bundles and sent to the ordnance store in the bath-room.

The personnel consisted of an officer of the R.A.M.C. in charge; a tent subdivision of a field ambulance; and 12 regimental fatigue men, with 4 civilians as overseer, mechanic, stoker, and bathman, and 52 washerwomen and 32 ironers and menders obtained from the local inhabitants.

As each company arrived it was lined up round the changing room and a N.C.O. from each platoon was told off to prevent the mixing of uniforms. The men were then ordered to undress. Each man first removed all valuables from his pockets and placed them in the pockets of his overcoat; he then took off his uniform and folded it into a bundle which he tied up with the cord of his identity disc. The men then fell in, wearing underclothing and boots and carrying the bundle of uniform. A batch of fourteen at a time was marched to the bathing room, placed their uniforms on a *red* trolley, which when full was wheeled into the ironing room. On entering the bath-room each man marched to one of the disinfecting tanks containing cresol solution, took off his underclothing and placed it in the tank, put his boots on a rack, and entered the bath. After washing and drying he received a complete clean set of underclothes and a clean towel from the store in the corner of the bath-room. Having dressed and put on his boots, he returned to the changing room, where his uniform, which had been ironed and again made up into a bundle, tied with the cord of the identity disc and sent back on a *white* trolley, was returned to him.

In the interval between the assembling of the companies the dirty towels in the bath-room were collected, placed in a disinfecting tank for twenty minutes, washed, made up into bundles, and returned to the store in the bath-room. The white trolley used for carrying the treated uniforms was washed with 5 per cent. cresol solution every night, and the women also washed their hands with a weak solution of cresol before leaving work.

The dirty underclothing, after steeping for twenty minutes in the cresol solution, was placed in tubs and wheeled to the washing room and placed in special tanks. After being washed, scrubbed, rinsed, and mangled, the clothing was sent to the drying room and then to the examining room, where clothes requiring mending were set apart and sent to that department.

The decision to establish the baths was made on 15th November, 1914, and the first batch of men had baths on the 17th, this organization being carried out by Captain J. B. Grogan, R.A.M.C.; but divisional baths of a similar or an even more elaborately organized character were established in all the divisions of the First and Second Armies during the winter of 1914–15.

In the mining districts of northern France the problem was considerably simplified by the fact that most of the mines possessed excellent baths with numerous sprays and an unlimited water supply. These establishments were placed freely at the disposal of the troops.

The object of the divisional baths was to turn large numbers of infested men into clean men as quickly as possible. The bathing and issue of clean underclothing was easily carried out, but the treatment of the uniform and cardigan jackets presented many difficulties. With the means then available, disinfestation by steam occupied too much time, as it was usually necessary for men to pass through the baths in a quarter of an hour. Ironing the infested clothes with a hot iron was

found the most practicable scheme, and determined the rate of bathing. It was found that the number of ironers must be equal to the number of bathers who could be passed through in a quarter of an hour. The officer placed in charge of the divisional baths had to possess organizing ability if the disinfestation was to be successful, and it was essential that he should be able to recognize from the condition of the lice or nits whether they had been subjected to treatment or not.

Experiments were made by Bacot and Lloyd to determine the measures necessary to disinfest clothing in these establishments. As already stated, the measure frequently employed was to steep the infested garments in a vat containing solutions of cresol. There existed, however, some uncertainty as to the strength of the solution and the period of immersion necessary to destroy the nits of *Pediculus humanus*, and in the interests

TABLE I.

Destruction of Nits of Pediculus humanus *by Immersion in Watery Solutions of Liquor cresoli saponatus fortis.*

Temperature.	Period of Immersion.	Strength of Solution. Per cent.	No. of Eggs.	No. Hatched.	No. Died while Hatching.	Percentage Mortality.
60–65° F.	5 minutes	2·0	94	3	7	97
		1·5	51	26	9	49
		1·0	69	37	10	46
		0·5	46	41	2	11
		0·2	79	64	2	19
	20 minutes	2·0	106	*Nil.*	—	100
		1·5	82	1	—	99
		1·0	93	5	4	95
		0·5	68	24	10	65
		0·2	37	30	3	19
	20 minutes	2·0	68	*Nil.*	—	100
	45 ,,	1·5	92	,,	—	100
	2 hours	1·0	64	,,	—	100
	2½ ,,	0·5	99	,,	—	100
	22 ,,	0·2	90	,,	—	100
48° F. ..	20 minutes	2·0	95	,,	—	100
		1·5	104	,,	—	100
	Control*	—	85	66	1	23
32° F. ..	20 minutes	2·0	137	1	1	99·3
		1·5	123	*Nil.*	—	100
	Control*	—	51	46	—	10

* The controls were exposed to the temperature but not immersed.

of economy it was desirable that overlapping methods of disinfestation should if possible be avoided. Hot water or dry heat at 55° C. destroyed both nits and active lice within thirty minutes, even when protected by a covering of khaki cloth; and if the temperature was raised to 60° C. fifteen minutes sufficed. Consequently, if at any period during the process of washing or drying garments were subjected to these temperatures and for these periods, chemical solutions were unnecessary; while, on the other hand, if the garments had been steeped in effective chemical solutions it was unnecessary subsequently to use temperatures so high as those required for washing or drying.

To test the strength of the chemical solution pieces of army shirt flannel on which numerous nits had been laid were immersed in the solutions for the periods shown in Tables I and II; they were then taken out and the superfluous fluid removed by placing them on filter paper for a few minutes. After this they were placed in small entomological boxes lined with a strip of dry flannel and carried in a thin cotton bag suspended from the neck between skin and shirt to enable the nits to incubate.

The experiment as a whole seemed to establish the fact that steeping for twenty minutes in a 2 per cent. solution of either lysol or cresol solution was effective, provided the temperature was not below 50° F.

TABLE II.

Destruction of Nits of Pediculus humanus *by Immersion in Watery Solutions of Lysol (equal parts of Crude Carbolic Acid and Soft Soap).*

Temperature.	Period of Immersion.	Strength of Solution. Per cent.	No. of Eggs.	No. Hatched.	No. Died while Hatching.	Percentage Mortality.
60–65° F.	5 minutes	2·0	120	*Nil.*	—	100
		1·5	121	,,	1	100
		1·0	82	2	6	98
		0·5	79	52	7	34
		0·2	89	70	2	21
	20 minutes	2·0	89	*Nil.*	—	100
		1·5	82	,,	—	100
		1·0	72	,,	1	100
		0·5	103	46	8	55
		0·2	94	60	8	34
48° F. ..	20 minutes	2·0	96	*Nil.*	—	100
		1·5	102	,,	1	100
32° F. ..	20 minutes	2·0	127	1	—	99·2
		1·5	99	7	2	93

Major Byam, R.A.M.C., also found that the trench fever virus in louse excreta was rendered harmless by immersion in lysol or cresol in 2 per cent. solution for twenty minutes at room temperature.

With the rapid growth of the expeditionary force supplementary bath-houses were established as opportunity offered; baths were improvised from wine-casks cut in half, hot water was supplied by Soyer stoves and various types of improvised boilers. Fuel was at times difficult to obtain, but frequently refuse destructors were used as a source of heat.

A transportable French shower-bath was much used in the French Army, and in October 1915 Major P. H. Henderson, D.A.D.M.S. of the 7th Division, obtained one for use in his division. The details of the apparatus are shown in Fig. 1.

The baths are made in three sizes, with four sprays, six sprays, and eight sprays, which cost respectively frs. 425, frs. 500 and frs. 600.

The one in use in the 7th Division was of the largest type, and was purchased through the French Société de Secours aux blessés.

The apparatus consisted of :—

(1) A cistern, H.
(2) A large and small iron tripod, A and B.
(3) A furnace, C, surrounded by a water-jacket or boiler, U.
(4) Spray piping, K, with eight sprays.
(5) Semi-rotary pump, M, with two lengths of hose, N and L.
(6) Foot-boards, S.

The entire apparatus fitted into four packing cases, T, and was easily transportable, the total weight, including cases, being 3 cwt.

In working the bath the cistern is first filled, after which the fire is lighted, and within ten minutes the water attains a temperature of 40° C., and with careful working will be delivered continuously at a temperature between 37° and 45° C.

One man is allotted to work the pump and ensure that the cistern is kept full.

In practice it was found perfectly easy to keep the cistern full with forty-five double strokes of the pump per minute and the expenditure of very little energy.

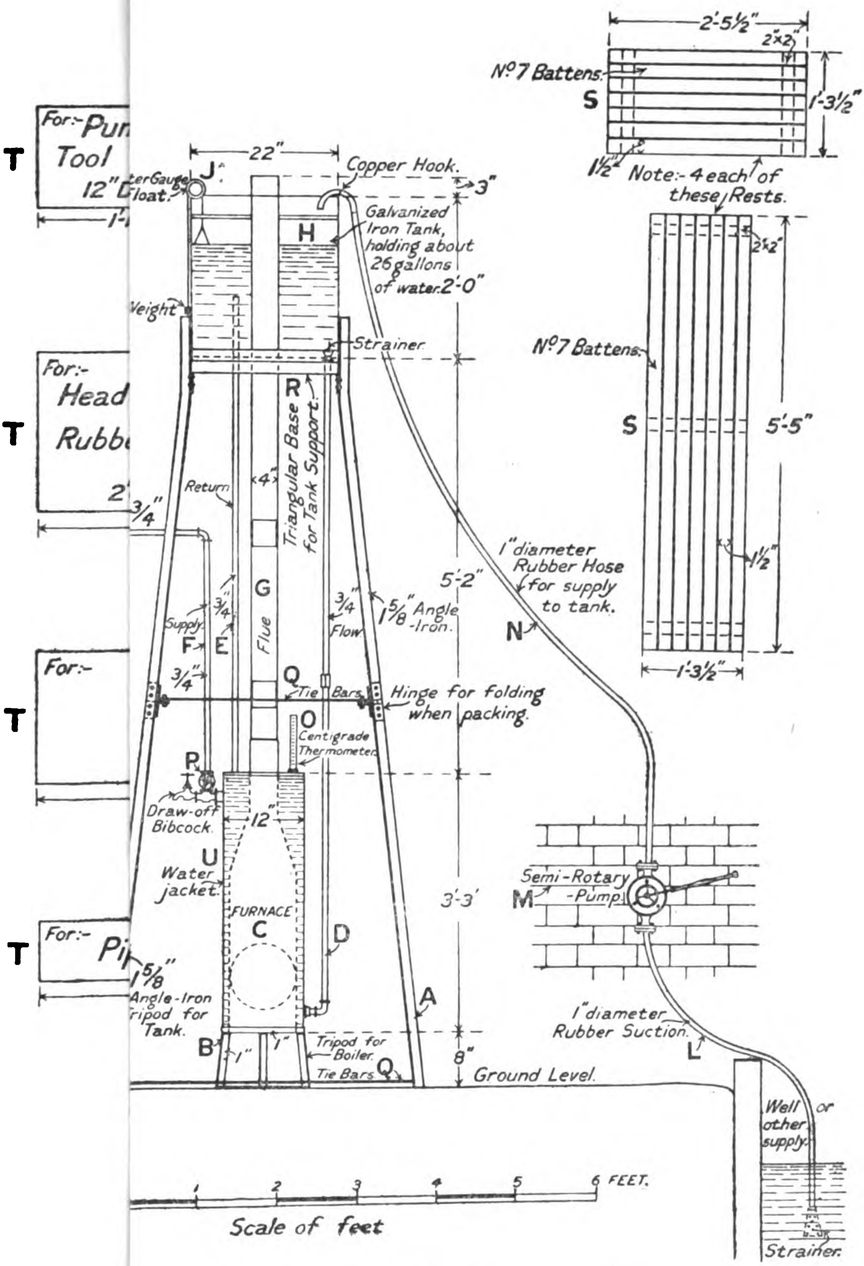
A second man stokes the fire and with a little practice very quickly acquired the necessary knowledge of how to keep the water at a uniform temperature of about 40° C., with the expenditure of on an average 40 to 50 lb. of coal a day.

The fire should never be very big, but stoked a little at a time and as often as necessary to maintain a good surface of live coal. Should the coal be of a soft nature it is necessary to add clinker about every hour.

A third man looks after the spray room and keeps it clean. He also superintends the supply of soap, regulates the number of men in the spray room, and prevents loitering.

Experience showed that by working from 8 a.m. to 12 noon and from 1 p.m. to 5 p.m., 600 men could be bathed during that time without undue pressure or crowding. This number should not be exceeded, but in an emergency a thousand men could be bathed in one day.

The spray room should not be less than 14 ft. by 14 ft., with a minimum height of 7 ft., but in summer the bath could be fixed up under a tree with a canvas screen to shut it off from public view. An impervious floor was of great advantage but was not essential.



2'-5½"
2"×2"
Nº7 Battens.
S
1'-3½"
1½"
Note:- 4 each of these Rests.
2"×2"
Nº7 Battens.
S
5'-5"
1½"
1'-3½"
T
For:- Pun
Tool
12" D
1'-
T
For:-
Head
Rubbe
2'
T
For:-
T
For:- Pi
22"
J
terGauge
Float.
Copper Hook.
3"
H
Galvanized Iron Tank, holding about 26 gallons of water. 2'-0"
Weight
Strainer
R
Triangular Base for Tank Support.
Return
4"
3/4"
G
Flue
Supply.
3/4"
F
E
3/4"
Flow
1⅝" Angle-Iron.
5'-2"
1" diameter Rubber Hose for supply to tank.
N
3/4"
Q
Tie Bars
Hinge for folding when packing.
O
Centigrade Thermometer
P
Draw-off Bibcock.
12"
U
Water jacket.
FURNACE
C
D
3'-3'
Semi-Rotary -Pump
M
1⅝" Angle-Iron Tripod for Tank.
A
1" diameter Rubber Suction.
L
B
1"
1"
Tripod for Boiler.
Tie Bars
Q
8"
Ground Level.
Well or other supply.
1
2
3
4
5
6 FEET.
Scale of feet
Strainer.

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The dressing room should communicate with the spray room, and be large enough, about 20 ft. by 20 ft., to accommodate thirty men at one time.

The quantity of water used is about one-third of a gallon per spray per minute, so that in bathing 600 men per day of eight hours, each man used a little over two gallons. As a rule, two men preferred to go under one spray at the same time, as by so doing they could wash one another's backs.

The apparatus is simple and easily worked, and with ordinary care, particularly in taking it to pieces for packing up and in putting it together, it would last for a long time.

One hour was required to take it down and pack it up, and about the same time to put it together and make it ready for baths.

The advantages of shower-baths of this description over tub-baths are obvious. They are more easily carried, occupy little space, and can be fitted up at any place where a water supply exists. By their use there is also a great saving in water, and although every man is washed in clean water there is less dirty water to dispose of—an important point in a water-logged country such as Flanders. The tub system required at least eight times as much fuel for the same number of men, much more soap, and a much larger staff.

With an eight-spray bath 600 men could be bathed in one day, and three such baths would consequently be sufficient to enable every man in a division to have a bath once in fourteen days.

Spray baths soon became popular and were even established in large dugouts in the trenches, the smallest size being used for this purpose. By 30th October, 1915, one hundred had been ordered for the British troops in France and twenty-five sets were distributed on 4th November, 1915.

Two of the French shower-baths were brought to Salonika by the 28th Division, to which Major Henderson had been transferred as D.A.D.M.S. In the summer they were moved from battalion to battalion both in the front and back areas. In the winter they were used as divisional baths. They proved of such value that the provision of four shower-baths was recommended by the Commander-in-Chief for each division.

Another method employed by the French for the disinfection of clothes and douching of men, and also for the sterilization of water, was by a specially constructed motor car, designed by a Bordeaux firm. Fig. 2 shows the apparatus ready for the road and Fig. 3 shows it opened out with the douches in position. This form of bath does not appear, however, to have been used with the British armies.

Towards the end of 1915 a portable bath-house capable of bathing 2,000 men in a day was presented to the 49th West Riding Division. This bath-house required twenty lorries or five railway trucks to move it and therefore was quite unsuitable for a mobile division. It was accordingly arranged with the donors that it should be used for troops billeted in the neighbourhood and four portable "French shower-baths" were given to the division in exchange.

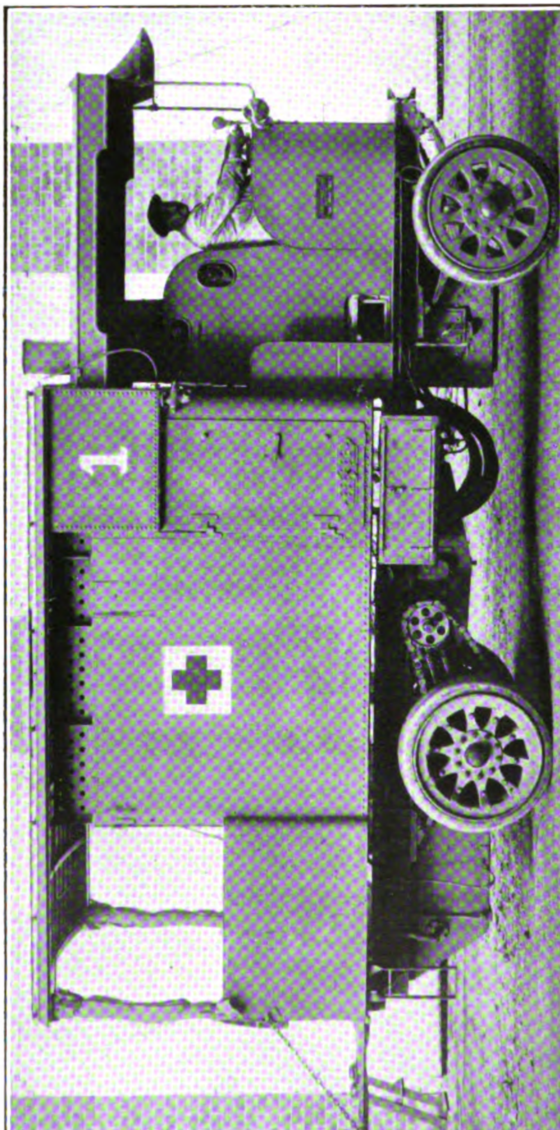

Fig. 2.—French motor-car douche bath, ready for the road.

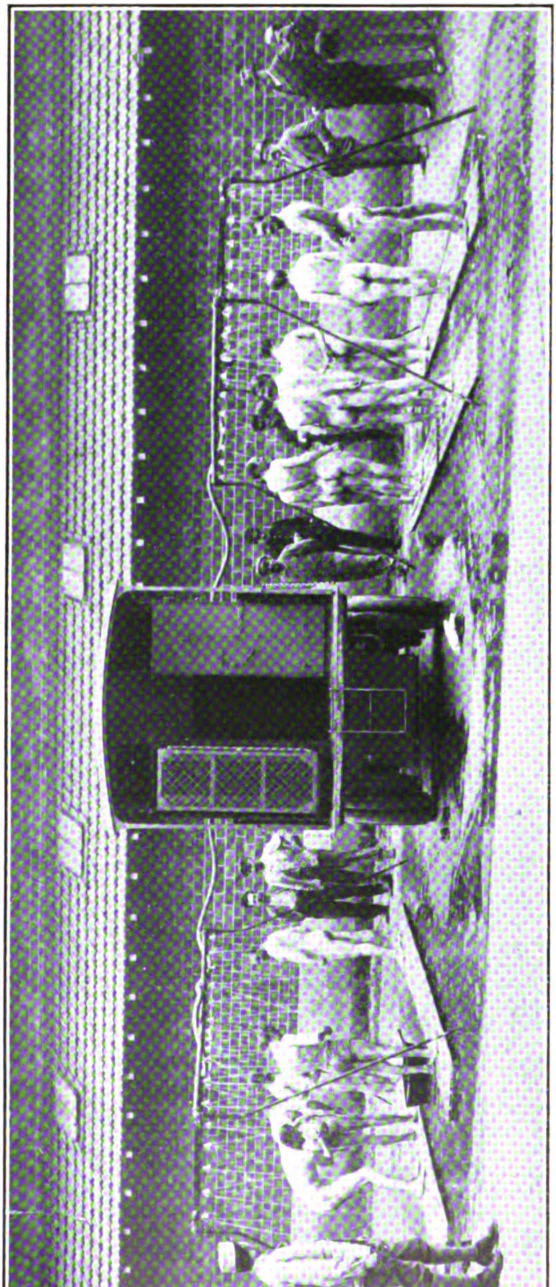

Fig. 3.—French motor-car douche bath, opened out with douches in position.

Vapour or steam baths were occasionally used in place of shower-baths. They were first employed by Lieut.-Colonel J. W. H. Houghton for hospital purposes at Rouen. The following is his account of the installation and method of working it: —

"The idea of utilizing steam for washing purposes at No. 11 Stationary Hospital was almost forced on us owing to the local difficulties in obtaining satisfactory ablution accommodation for personnel and patients. The difficulties were lack of means for the disposal of waste water and the absence of a piped water supply.

"Both these difficulties were met by the steam vapour-bath. The amount of waste water requiring disposal is so small as to be negligible, and the amount of water required to generate the steam does not amount to more than a few pints.

"The construction of the bath arrangements is simple and inexpensive. The bath-chamber is formed by screening off with tarpaulin a corner of a drying room, 15 ft. long by 8 ft. wide and 6 ft. high.

"The walls and roof of the chamber are formed by a double layer of tarpaulins stretched tightly over 4 in. by 2 in. quartering. This double layer of tarpaulin encloses an air space which greatly helps in the conservancy of heat.

"A small entrance door is closed by a flap of tarpaulin on the inside and a sheet on the outside. This arrangement retains the steam. The exit is formed by a flap of tarpaulin which opens directly on to the douche grating. Dressing accommodation is provided in the unused portion of the drying room.

"Steam is led in a rubber tube from the exhaust pipe of a Manlove, Alliott disinfector and distributed through a perforated zinc pipe along the floor of the steam chamber. A removable wooden grating covers the floor and a window in the outer wall provides light and ventilation.

"With a fifteen-pound head of steam in the disinfector the temperature in the chamber is raised to 100° F. in five minutes. The bathers undress and enter the chamber. Steam is turned on and at 80° F. they begin to sweat. At 90° F. they perspire sufficiently to raise a good lather on their bodies with the soap provided. The temperature is not raised above 100° F., as a minute or two in that moist heat causes profuse sweating from all the pores and the indiviudal is thoroughly cleansed. Still covered with a soapy lather, the bather emerges and a bucket of cold water is thrown over him. This produces a pleasant reaction and prevents further loss of body heat. He dries himself and dresses.

"The time occupied by each individual in undressing, bathing and dressing is fifteen minutes.

"The chamber in use at No. 11 Stationary Hospital accommodated 15 men, so that 60 men per hour could easily be passed through. This has sufficed all local needs, but a Manlove, Alliott & Co.'s disinfector can provide steam for a chamber twice as large with a slight prolongation of the time required to raise the temperature to 100° F.

"Apart from the cleansing of healthy men, cases of myalgia and skin disorders have received much benefit from the frequent use of this vapour bath. The men and officers like it and its popularity has extended to the nursing sisters.

"The times of bathing and disinfection of clothing are synchronized as much as possible to economize fuel; both proceedings are carried on at the same time with the same disinfector.

"A bucket of cold water is kept in the steam chamber for the use of those who get soap-suds into their eyes. A thermometer is kept in the bath and read at minute intervals, and the following orders have been issued for the bath attendant:—

(1) The bath attendant will always be present whilst the bath is in use.

(2) The bath will not be used except by two or more persons at the same time.
(3) The temperature in the bath must not exceed 100° F. = 37·7° C.
(4) Time for each bather will not exceed five minutes.
(5) A masseur will attend when necessary.
(6) The bath attendant will obtain from ward-masters the number of patients detailed for a bath, and arrange for their arrival at suitable times.
(7) The bath attendant will be responsible for the custody of all property in the bath-room, also for:—
    (*a*) The cleanliness of the bath-room.
    (*b*) The ventilation of the hot chamber.
    (*c*) The turning on and off of the steam.

(8) If any bather should feel faint he will immediately be removed from the bath, laid flat on the floor and douched with cold water, the orderly officer being sent for.

"Both the Director of Works and the D.M.S. of the lines of communication in France subsequently issued similar instructions in the form of memoranda on the use of steam-baths for general information."

Where specially constructed shower-baths were not available they were improvised out of perforated cresol drums raised to a suitable height, the drums being filled with warm water from a platform. The perforations had to be fine and so arranged that an ordinary cresol drum emptied itself in about five to eight minutes. This type of shower-bath was frequently used in the eastern theatres of war.

Disinfestation of Clothing and Bedding.

For the destruction of lice in clothing on a large scale the most efficient method consisted in the application of dry or moist heat.

The experiments of Nuttall, Bacot and other observers showed that adult lice are killed by dry heat at 65–70° C. in one minute and at 55° C. in five minutes. Nits and active stages of lice appear to be equally susceptible to the effects of heat. At one time infested garments were exposed to needlessly high temperatures. Nuttall, as the result of his experimental work, urged on those who had to do with practical disinfestation to employ lower temperatures (55–70° C.) for killing lice. Experiments under practical conditions were carried out at Nuttall's suggestion by Captain H. Orr, of the Canadian Army Medical Corps, who found that lice and nits placed in various parts of a hut were killed by exposure for fifteen minutes to dry heat at 54° C. Captain J. T. Grant and Lieutenant A. D. Peacock, Royal Army Medical Corps, carried out for the War Office experiments in hot-air disinfestation huts containing blankets or clothing with living lice and nits. Active lice to the number of 15 to 20 and 50 to 100 nits were used for each

test, the insects being contained in gauze-covered pill-boxes or attached to cloth. Maximum thermometers were used for recording the temperature, and the exposure time was reckoned from the moment that the desired maximum temperature was attained in the hut. The test insects were distributed in various parts of the hut in the pockets of clothing. After the lice had been exposed they were kept under observation to determine if any had survived. The results were that lice exposed to 48° C. for sixty minutes and below survived, that active stages of lice, but not nits, were killed at an exposure to a temperature of 51–53° C. for fifteen minutes, and that all lice and nits exposed to 55° C. and over for thirty minutes were killed. In order to allow a margin of safety under working conditions Orr adopted an exposure of 60–65° C. for fifteen minutes. Grant and Peacock recommended an exposure of 65° C. for thirty minutes. The question of the temperature to which infested clothing should be exposed was raised by the War Office when the Trench Fever Committee's experiments showed that the excreta of lice which had fed on trench fever patients were infective for human beings. To determine this Major Byam conducted experiments which were necessarily few in number as they had to be carried out on human beings. His results showed that the virus in excreta of trench fever infested lice was not killed by exposure to a dry heat of 80·5° C. for twenty minutes, but was killed by an exposure to a temperature of 100° C. for twenty minutes.

Active stages of lice and nits are killed instantaneously by immersion in water at 90°–100° C. and even an exposure of five seconds at 70° C. is fatal. Nuttall found that nits exposed for one minute in a steam jet at 90° C. became coagulated and promptly collapsed. Although it is evident that steam at 100° C. will kill lice and nits instantly, in practice the exposure must be lengthened when steam is applied to clothing, to ensure the penetration of the steam into the clothes and their folds, seams and pockets. When steam disinfectors are overloaded and insufficient time is allowed for the steam to penetrate the clothing the lice will survive. From practical considerations Nuttall consequently recommended that a period of fifteen minutes should be allowed to elapse after the thermometer has reached 100° C. in the least accessible parts of the articles exposed to the steam.

Major Byam found that the virus in the excreta of trench fever infected lice was destroyed by exposure to moist heat at a temperature of 60° C. for twenty minutes. The American Red

Cross Commission on trench fever did not confirm this statement, but found that the virus was destroyed by exposure to 70° C. moist heat for thirty minutes.

At the outbreak of war there was no method of disinfestation available apart from the disinfectors which were intended primarily for the disinfection of clothes after exposure to infectious disease. The disinfectors supplied to the troops made use of current or high-pressure steam. The portable machines were a portable field disinfecting box, capable of dealing with six soldiers' kits or eight blankets at a time, the exposure to current steam lasting thirty minutes; the horse-drawn Thresh steam disinfector, employing current steam at a temperature of about 215° F., and capable of disinfecting thirty blankets or twenty kits in one hour; and Alliott and Paton's "medium oven," dealing with sixty blankets or thirty-five kits in one hour. The fixed machines were the usual standard types manufactured by Thresh, Alliott and Paton, Barford and Perkins, the Grampian and the Equifex Companies. They were used in the hospitals at home, at bases and in large hospital camps on the lines of communication in the various theatres of war. The horse-drawn Thresh machines were supplied to general and stationary hospitals, casualty clearing stations, and to divisions in the field. They did excellent work when not overloaded, but they were too small to grapple with the problem of disinfesting divisions either at home or in the field and became useless as mobile apparatus. They were too heavy for one-horse draught and the wheels were of a material which broke readily. Their main use was for disinfecting clothing at hospitals and casualty clearing stations.

The disinfestation of divisions at home during mobilization was dealt with in 1914 and 1915 by the sulphur dioxide process. This was first tested at Aldershot, where a petrol-driven machine was used to supply sulphur dioxide to a large hut of 3,000 cub. ft. capacity, in which some 600 blankets could be treated at one time. Many thousands of articles of clothing left by divisions on their departure for France were disinfested and rendered capable of re-issue, thus enabling a large saving to be effected. Special huts were constructed later in other camps in England and France, and sulphur dioxide machines were also supplied to corps in the field. Experience in the field with sulphur dioxide showed that it had several drawbacks, the principal of which were the difficulty of dealing with damp articles of clothing which absorb large quantities

of SO_2 gas, the difficulty of deciding when the lice and ova are destroyed, and the difficulty of providing gas-tight chambers in forward areas. At bases, where the conditions were little different from those of peace time, the process was found very useful for the disinfestation of ships.

Disinfestation by Steam.

In France, Thresh disinfector chambers mounted on a Foden steam lorry were used for divisional disinfestation work. This disinfector had the advantage of much greater mobility than the horse-drawn machines. It had two chambers each having a capacity of 60 cub. ft. and capable of being used together or singly. Heating takes place rapidly when the lorry arrives at its destination because the steam from the engine that runs the lorry is then diverted into the chambers. The temperature attained is somewhat over 100° C., the steam pressure not exceeding 5 lb. About 112 lb. of fuel are required to start the machine from the cold and obtain a pressure of 5 lb. in both chambers; after that the fuel consumption is about 70 lb. per hour. It was ascertained that 100 blankets or 50 kits consisting of jackets, trousers, cardigan, shirt, pants and socks could be disinfested at one time using both chambers. If a greatcoat was added to the kit then only about 25 kits could be disinfested. The time required for each operation was seven minutes for loading, forty-five minutes for disinfesting, and eight minutes for unloading. In practice it was found that at the end of steaming, articles could be taken out, shaken and used at once without drying. The process of loading and unloading was found to be greatly facilitated by fitting the lorry with a stout wooden platform 3 ft. 6 in. wide, running the length of the body and hinged upon an iron bar which extended along the side of the vehicle. The platform was supported at its outer edge by three hinged legs and was tied up vertically when the machine was on the road.

A Foden–Thresh machine was eventually supplied to each division and also to each corps in France. In practice it was found to be too heavy for a cavalry division and a lighter machine with one chamber on a motor was recommended.

Serbian Barrel Disinfector.

A barrel disinfector employing steam was devised by Lieut.-Colonel G. E. F. Stammers, R.A.M.C., for use during the typhus epidemic in Serbia. It became known as the Serbian barrel

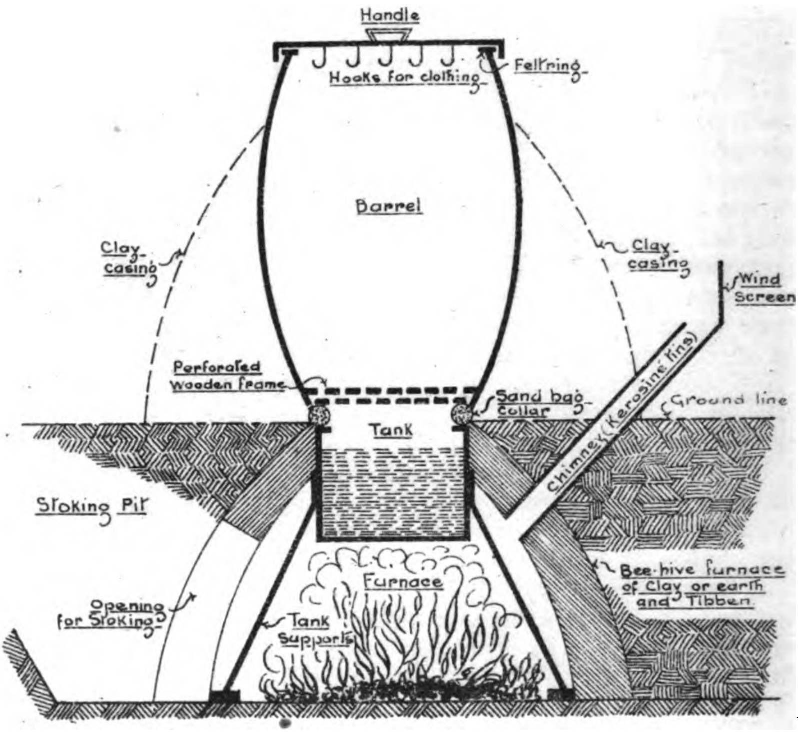

FIG. 4.

UNDERGROUND BEEHIVE FURNACE FOR A "SERBIAN BARREL".

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disinfector and was much used by units in Gallipoli, Salonika, Egypt, and Palestine.*

A description, with sketch, of this disinfector was also issued to the troops in France, where it was extensively used, and a method of fixing it on an underground or beehive furnace is shown in Fig. 4.

An improvised steam disinfector made of available waste material and similar in principle to the Serbian barrel was found useful in France for disinfesting small quantities of clothing where larger and more permanent disinfectors were not available. The materials required were three sheets of corrugated iron, six angle-irons, two oil drums, one slightly larger drum or a 9·2 howitzer cartridge canister, a length of stove piping or biscuit tin rolled to make a chimney, some wire, and clay or mud for luting.

The following is a description of the method of making this improvised disinfector.

The corrugated iron sheets are bent or cut with an entrenching tool to form the two sides, the roof and back of box, the furnace-box, and the fire-grid. Six inches from the base two angle-irons are hammered through the sides to serve as supports for the fire-grid. This latter consists of corrugated iron with holes punched in it, or stout expanded metal may be used instead. At the back end of the furnace a hole is cut for the chimney. In the centre of the roof a circular hole is cut just large enough to admit one of the drums which is dropped through it and is supported on two angle-irons driven through the sides of the furnace. This drum serves as a boiler and when in position on its angle-iron supports the top of the drum should project a couple of inches through the roof. Two more angle-irons are hammered through the sides higher up so as to grip and steady the boiler ; they also add to the stability of the furnace. The various parts of the furnace are now assembled and wired together and the boiler placed in position. The flange of the second oil drum, which is to serve as the sterilizing chamber, is opened out a little so that it may overlap and grip the mouth of the boiler when placed above it. A large hole is cut in the bottom of this upper drum so as to allow free passage of steam from the boiler and a disc of

* It is of interest to note that a similar disinfector was used by some of the Japanese units during the Russo-Japanese War. A photograph and description of one of these are included in the Medical and Sanitary Reports of the Russo-Japanese War, p. 475, published by H.M. Stationery Office, 1908.

wire netting is dropped into the drum to support the clothing. The top of the drum is left open. All joints are finally luted with clay. The larger drum or cartridge canister is inverted over the upper drum during disinfestation and acts as an outer jacket and materially diminishes the condensation of steam on the clothing. Two sets of drums can be fitted into one furnace, thus doubling the capacity of the disinfector.

To use this improvised apparatus, the boiler is filled two-thirds full with water and the fire lighted. Wood was the most suitable fuel, but coal, coke and rubbish could be used. When the water is boiling the upper drum is fitted on and allowed to heat. The clothing to be disinfected is then dropped loosely into the drum and the outer jacket placed in position over the drum. Brisk boiling should be maintained, and if this is done disinfestation should be complete in about five minutes. The clothing on removal should be briskly shaken in the air and will then dry rapidly. Water should be added to the boiler in small quantities at frequent intervals so as to make good the loss of steam.

A single drum is capable of holding five shirts or pairs of pants, one complete uniform, one overcoat, or one blanket. When working efficiently it should be possible to deal with five or six charges per hour, so that sixty shirts or pants, or twelve complete uniforms, overcoats, or blankets can be disinfested in an hour. With two sets of drums, which can be made and worked as easily on one furnace, double that number of articles can be dealt with in the same time.

A boiler and sack disinfector was designed by Lieut.-Colonel Lelean, R.A.M.C., to provide a simple and portable means for disinfesting troops in the field, which would replace other "portable" disinfectors weighing several hundredweight, and the rigid apparatus such as Serbian barrels, which were too bulky to carry. It proved a success in Egypt. The principle involved is that of the passage of current steam through clothing by downward displacement in a collapsible, waterproof sack, from which surplus air has been expressed and from which loss of heat is minimized by the insulating action of a hot-air chamber.

The portable parts are easily made in the field and weigh 50 lb. They comprise the following articles :—

A 10-gall. boiler made of a large oil drum set on its side, fitted with 5 ft. of 1-in. iron pipe, as in Fig. 5, with a screw tap at the summit of the angles. The pipe is made to screw on and off.

A sack 5 ft. long and 2 ft. in diameter, with 5-ft. length of 2-in. canvas hose attached to the margins of a hole in a wooden disc at one end, and having a

purse-string mouth at the other end. Sack and hose are made waterproof. The capacity of the sack is 15 cub. ft.

Six fire-bars, each $1\frac{3}{4}$ ft. long, of $\frac{3}{4}$ in. by $\frac{1}{8}$ in. angle-iron.

One disc of corrugated iron, 1 ft. 9 in. in diameter.

The non-portable parts are constructed of mud, stones or similar material and form the furnace, flue, chimney, and an insulating hot-air chamber, containing the sack and hose

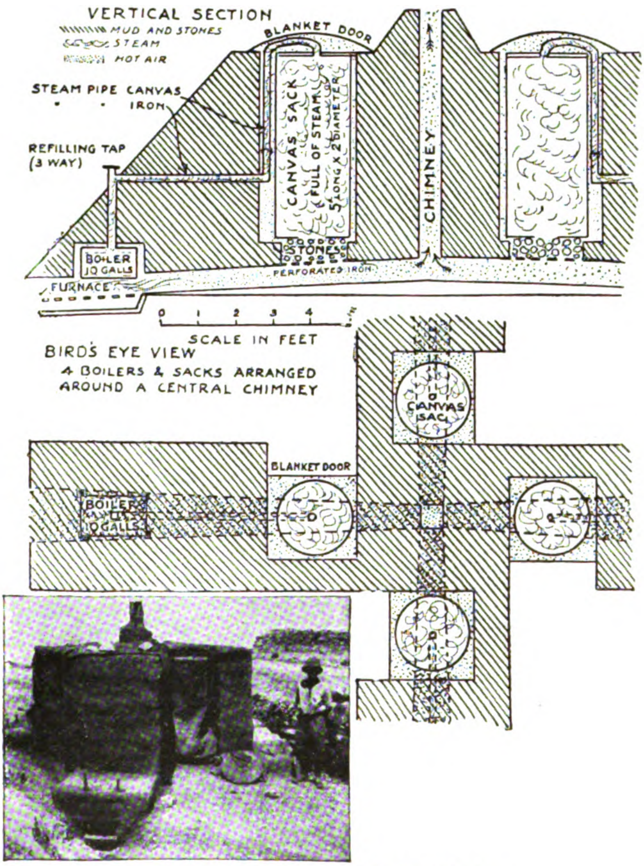

Fig. 5.—Boiler and Sack Disinfector.

and with its walls extended so as to imbed the boiler and steam pipe.

Hot air enters the base of the insulating chamber through the roof of the flue over which it is placed, intervening layers of perforated corrugated iron and stones preventing the sack

from being scorched. One side of this chamber and its top are closed by blankets, or the sack may be enclosed by blankets spread on a light wire frame.

An installation of this kind can be made of four sets radiating from a central chimney as shown in the figure.

The method of working is as follows: Seven gallons of water are run into the boiler and a strong fire set going. Steam should be generated in fifteen minutes. The canvas hose is then bound to the free end of the metal pipe, the sack mouth turned upwards and filled with kits each tied up in a blanket with the owner's identity disc attached. The purse-string mouth is then drawn together, the sack turned upside down and as much air as possible pressed out. The tap is then closed and the steam turned into the sack for twenty-five minutes while the roof and door of the hot-air chamber are kept closed by blankets. The steam is then turned off, the mouth of sack opened and the kits shaken out, each man opening his own blanket and shaking his clothing for a few seconds until they are dry. The process of filling, disinfesting, and emptying takes thirty minutes for each charge. A brisk fire must be kept going and 1½ gallons of hot water added to the boiler every two hours through the refilling tap.

For transport, the sack, boiler and pipe are disconnected. The boiler, iron-plate, fire-bars and steam pipe, are placed in the sack; the purse-string is tightened and the sack rolled up around its contents. Three sets form a suitable load of 150 lb. for one mule and are sufficient for use with a brigade.

The working capacity admits of one charge of ten summer kits in each sack, each kit consisting of four socks, two shirts, a pair of shorts, a tunic, puttees, blanket and towel.

Owing to the small amount of non-conducting air left in the sack and the uniform downward displacement of air by steam in successive layers, penetration is very rapid. For example, egg albumen wrapped in sixteen layers of blanket was coagulated in two and three-quarter minutes and meat cubes of dice size had their myosin coagulated in seven minutes. When fully charged with very verminous articles well wrapped up centrally, all lice were killed after twenty minutes and all ova were cremated and browned in twenty-three minutes.

As bundles are rapidly put into the sack, and more rapidly shaken out, the whole process of filling, steaming, and emptying takes well under thirty minutes, and two charges of ten kits each can be treated in an hour.

Consequently, by working three boilers and sacks, or one mule load, for eight hours the summer kits of 480 men can be disinfested in a day, or a brigade in eight days. The winter kits of a brigade would require sixteen days, a period which is within the limit of time occupied by one cycle of louse reproduction.

The fuel and water requirements are 2½ lb. wood (or 1·07 lb. coal) and about ⅔ pint of water for each kit.

These compare favourably with the fuel and water required for a Thresh disinfector which is estimated to use 1·1 lb. of coal and 1½ pints of water for each kit, the number disinfested in one hour being nineteen in the Thresh as compared with twenty in the sack disinfestor. The sacks are made of sail canvas and they are waterproofed by painting with a mixture of 56 lb. of lamp-black, 7 lb. of driers (dissolved in 5 pints of water), 2 gall. of linseed oil, and 2 lb. of soap.

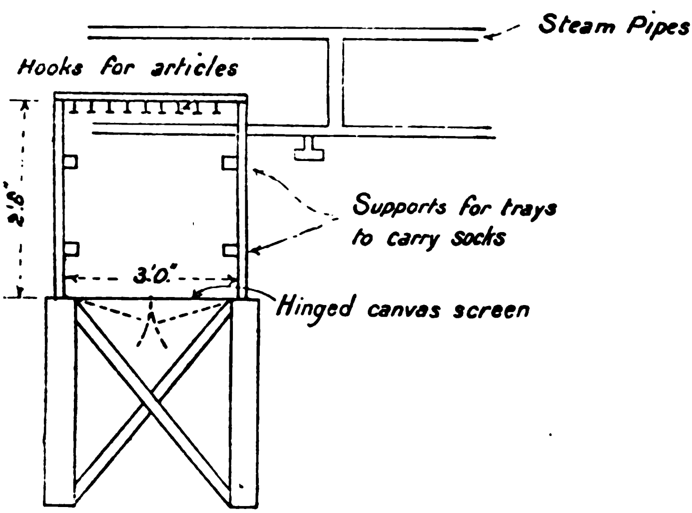

Fig. 6.—Improvised steam disinfector.

Another improvised steam disinfector was designed by Major J. Dale, R.A.M.C., and was used in many camps on the lines of communication in France with satisfactory results. It was cheap, light, rapidly constructed, economical, and convenient to work. (Fig. 6.)

It was formed of rectangular boxes or chambers made of tongued and grooved planking and "lugged" on the outside to prevent loss of heat. The interior of the box was lined with

felt or blanket material. Each box was 6 ft. long, 3 ft. wide and 2½ ft. deep, and was open at the bottom. The ends of the boxes were fixed by nuts and bolts and were detachable to form doors.

Each box is raised in a horizontal position on struts 3 ft. high so that the top or roof of the box is 5½ ft. above the ground.

Underneath the roof of each box are hooks on which articles to be disinfected are hung. Steam is admitted by a pipe which enters one side of the box a few inches below the centre of its upper edge. This pipe passes horizontally across the inside of the box to within a few inches of the opposite side. The pipe inside the box may be perforated. A metal gutter may also be fixed to catch water which falls from the end of the pipes.

In loading a box the doors or ends of the boxes are removed. A man enters from either end and hangs the articles upon the hooks. He begins at the middle of the box and works backwards towards the door. Each article is hung so that its lower end does not quite reach to the level of the bottom of the box. A full load for a box of the dimensions given above is 144 shirts, pants, or trousers, or 36 blankets. Socks are disinfected separately. They should be unfolded and piled loosely upon trays.

When the box is charged the doors are clamped in position and steam is admitted. The steam gradually passes round the top of the box, displaces the air downwards and condenses upon the upper ends of the articles. The temperature of the latter is raised to 100° C. As more steam enters it displaces the air farther down until finally the steam escapes freely all round the bottom of the box. The disinfection is then completed and the steam is shut off. The chamber is opened at both ends and emptied. It is advisable to fit the boxes with a light hinged bottom of canvas on a wooden frame. On very windy days these bottoms can be hooked up to prevent draughts from interfering with the even descent and escape of the steam.

Articles do not require drying. Outer clothing or blankets, if shaken vigorously for a few moments, can be worn and used at once.

The chambers are used in pairs. While one is unloaded and charged again the other is steamed.

As a source of steam for a two-chamber station it has been found that the smallest pressure-boiler obtainable is sufficient. Steam pressure of three to five atmospheres can be maintained and the steam is supplied to the chambers through a ¾-in. pipe.

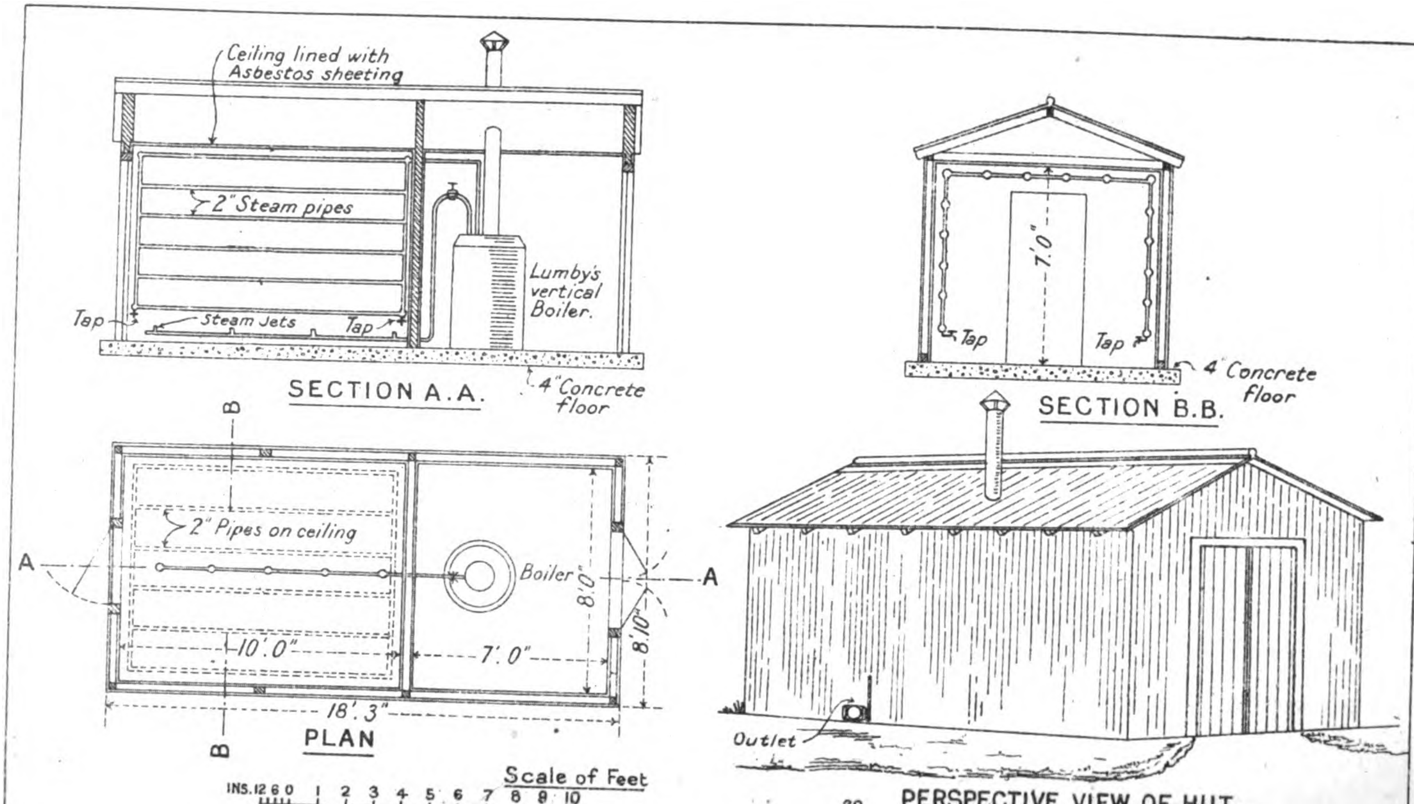

FIG. 7. STEAM DISINFECTING HUT.

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The time required for the disinfection of a box with a boiler of this kind is twenty to thirty minutes. The steam begins to escape in from fifteen to twenty-five minutes, and is allowed to escape for five minutes. This is probably the minimum time required for disinfection. If steam is admitted too fast it " spills over " at the bottom very soon and it is then difficult to judge when disinfection is complete.

A two-chamber station during nine months did about as much work as a " Foden " lorry disinfector. Chambers of this type could be erected wherever a steam generator was available, and it is estimated that an eight-chamber station could deal with 70,000 to 80,000 pieces of underclothing in a week.

Hut for Disinfestation by Steam.

In order to deal with larger quantities of clothing Captain J. T. Grant devised a hut for steam disinfestation (Fig. 7). The first hut was erected at East Sandling, Kent, for the hospital of the 1st Canadian Reserve Brigade.

" The framework was of wood, the inside walls and flat ceiling of uralite, the outside walls and roof of corrugated iron or sheet asbestos. The 2-in. space between inner and outer walls was filled with sawdust, the floor was of concrete, and from it a channel ran through the wall to carry off condensation water.

" On the inside walls and ceiling there were 2-in. radiator pipes containing steam introduced by a special direct pipe from the boiler-head under the same pressure as in the boiler. There are six of these pipes in the ceiling and six running horizontally along each side wall. The tap for running off condensation water was on each side near the door and 3 in. below the junction of the horizontal pipe.

" The boiler-house was merely a wooden framework, supporting walls and sloping roof of corrugated iron. A wooden grid, 7 ft. long, 3 ft. wide, and 6 in. high on the floor of the steam chamber facilitated the handling of blankets by those of less than average height, and also kept the feet clear of the floor which became wet with condensation water. The overall dimensions of the combined steam chamber and boiler-house were 18 ft. 3 in. long and 8 ft. 9 in. wide. The inside measurements of the steam chamber were 10 ft. in length by 8 ft. in width and 7 ft. in height. A height of 6 ft. 9 in., however, is more suitable for hanging and unhooking the articles for disinfestation. The boiler had a working pressure of 7 lb. with a test pressure of 60 lb. It was, however, found desirable to work at a pressure of 15 to 20 lb. in order to obtain the highest temperature more rapidly and to increase the penetrating power. The steam was introduced to the chamber by a pipe running from the boiler along the centre of the floor to within 1½ ft. of the door, and fitted with four 1-in. vertical jets standing 1 in. above the pipe at intervals of 2 ft., the end being closed and a drain-cock inserted. It may be found advisable to fit a mushroom disperser over the steam outlets to prevent the steam rising vertically and unduly wetting the adjacent articles, but if the centre bar of the grid floor is placed vertically over the steam outlets this would serve the same purpose. Again, the inclination of the steam nozzle outlets to right and left alternately would assist dispersion. The steam pipe should be inclined to the drain-cock and fixed to the floor by holdfasts and supports.

"The blankets or garments are hung each on a slideable iron hook, 200 of which are suspended from the radiator pipes on the ceiling. Coat hangers could also be used. If the space be not already occupied by bulky articles such as blankets, a lower tier of bars and hooks may be arranged for underclothing, socks, and small articles. The radiator pipes attain the same temperature as that of the boiler and at the same time. The door being closed and fastened and the pressure indicated being 15 to 20 lb., steam is admitted, at first gradually, through the jets of the steam pipe on the floor for thirty minutes, at the end of which time the door is opened for a few minutes to allow escape of steam and the taps on the radiator pipes are opened for a few minutes to allow the condensed water to flow out. The blankets and other articles are then removed, each being held by two men and shaken twice in order to dry it. At every second operation cold water has to be fed to the boiler.

"After turning on steam under 15 to 20 lb. pressure an average test with the maximum thermometer placed within a double fold of blanket and projecting 6 in. through a hole in the door, either 15 in. or 3½ ft. from the floor, read as follows:—

2½ minutes	70° C.
5 "	85°
10 "	90°
15 "	95°
20 "	100°
30 "	100°

"After turning on steam under 15 to 20 lb. pressure, an average test with a maximum thermometer similarly situated but within four thicknesses of blanket gave the following readings:—

5 minutes	80° C.
10 "	83°
15 "	85°
20 "	90°
25 "	95°
30 "	95°

"The chamber was repeatedly tested against *B. typhosus*, *Staphylococcus aureus*, and *B. coli*, and against lice and their ova, and found to be lethal even though the period of steaming had been reduced to twenty minutes instead of thirty.

"One chamber required a staff of 1 N.C.O. and 6 men. For the management of the boiler one permanent man was required. The amount of coal used for 6 loads, 6 days a week, was 7 cwt. It was a good plan to bank the fire with dross or screenings in the evening, as by this means the boiler was kept warm and steam was more rapidly obtained in the morning.

"Compared with steam disinfectors of a proprietory nature, this system was much less expensive in initial and running cost and did much more work in shorter time.

"To prevent contamination of disinfected material, a receiving room and a despatching room were required for infected or infested and disinfected or disinfested material respectively, and where permanent buildings were unobtainable two separate marquees could be used."

Experience with this hut showed that it was better to have the 2-in. space between the inner and the outer walls occupied by air in preference to sawdust, which was apt to get wet and led to loss of heat. Professor Nuttall suggested that it would be an improvement to sink the boiler in a well, as is usually done with boilers supplying radiators heated either with steam or hot water. The water condensing from the steam in the

radiator pipes would not then have to be periodically drained off but would flow back by gravitation to the boiler. Many of these steam huts were erected by Canadian and Australian troops in France and were found very satisfactory. Later on they were used extensively in France at divisional and corps bathing establishments and at disinfecting stations. They were also erected in many camps in the United Kingdom.

Captain Robinson, R.A.M.C., in charge of No. 49 Sanitary Section, devised a portable form of the Grant hut. The boiler was of the Merryweather type. The disinfector was built by the sanitary section and was carried in a general service waggon. The blankets and kit were hung on the wheeled frame which was run into the machine. The hut was easily put into action and was much used in forward areas in France.

A steam disinfector, based on the Grant type, for use in permanent camps was designed by Lieut.-Colonel Rudd, of the Army Ordnance Department. It consisted of two chambers erected in a well-ventilated building, the side for the reception of infected clothing being completely cut off from the side into which the disinfected clothing was delivered. Current steam was employed and was first passed into steam coils placed on the sides and floor of each chamber. When the chamber was warm the steam was delivered into the interior by jets placed in the roof. There was an ingenious arrangement of trolley rails which could be run out from the disinfecting chamber. The clothing was loaded on the rails, which were then run back again, the doors of the chamber being closed during loading to prevent loss of heat. By having two chambers the disinfecting work could be made practically continuous, one chamber being loaded while disinfection was carried out in the other.

Colonel Rudd also devised a mobile disinfector. This consisted of a van having two disinfecting chambers mounted on a wheeled under-carriage, arranged for transportation as a trailer, the total weight of the vehicle being 4 tons 7 cwt.

In a compartment between the disinfesting chambers were carried the steam boiler, fuel tank, compressed air cylinder, and other accessories of the steam plant. Steam was taken from the boiler to a four-way connection fixed in the roof of this compartment, from which valves and pipes were led to the radiators and spray pipes in the disinfesting chambers.

Condensation water from the radiators passed through a steam trap to the hot-water tank fixed underneath the van body, from which the feed water was pumped into the steam boiler.

The dimensions of each chamber were 4 ft. 9 in. by 5 ft. 8 in.

by 6 ft. The chambers were fitted with radiator, steam spray pipes, rails and spring clips for carrying the articles, and also with air-valves manipulated from outside the van on the top and floor of the chamber.

The radiators were of 1½-in. steel tubing giving about 50 sq. ft. of heating surface in each chamber. The sides and roof of the chambers were insulated, the insulating space being filled with old army blankets. The lining of the chambers was uralite supported on thin wood.

The steam boiler was of the water-tube Merryweather pattern, using ordinary paraffin as fuel, and evaporating 235 lb. of water per hour, and was of sufficient capacity for working the two disinfesting chambers simultaneously.

In commencing to work the disinfestor, compressed air is first used in the burner or atomizer until the pressure of steam in the boiler is sufficiently high (from 15 to 20 lb. per square inch), when the air is shut off and the atomizer continues to be worked by the steam from the boiler.

An alternative arrangement for raising the steam for working the atomizer, which it was proposed to adopt, consisted of a circular tray underneath the boiler fire-box. Oil is admitted to this tray through the burner and ignited. Air for combustion is supplied through the nipples or jets in the bottom of the tray.

Starting from cold, the necessary pressure for working the steam atomizer is obtained in about ten minutes, when the steam from the boiler to the atomizer is turned on, and the working pressure required for the radiators is then reached in about fifteen minutes.

The doors on each side of the chamber when opened formed a platform. The rails could be drawn out on to the platform and loading and unloading carried out without entering the chamber. In working the apparatus, after the chamber had been loaded and the doors closed steam was introduced into the radiators for ten minutes to warm the chamber and prevent condensation of steam in the clothing. Steam was then introduced into the body through the jet placed in the roof; the air in the chamber was forced out through the valve in the bottom of the chamber. To ensure disinfestation articles had to be exposed for thirty minutes to the current steam, the time of exposure being counted from the appearance of steam at the outlet in the floor of the air chamber.

For disinfestation it was sufficient to warm the chamber for ten minutes, turn on the current for five minutes, and then shut

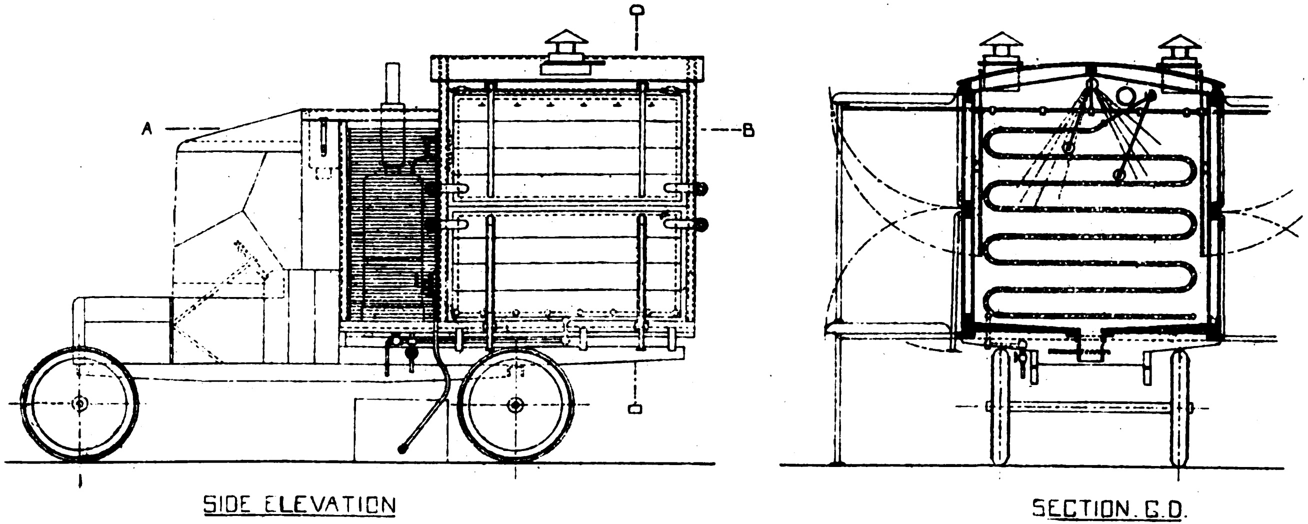


FIG. 8.

THE RUDD PORTABLE DISINFECTOR ON FORD CHASSIS.

Malby & Sons, Lith.

off the steam, closing the outlet valves and keeping the air chamber closed for a further ten minutes.

An apparatus of this construction was useful for work in the United Kingdom and for army areas. Its weight was against its use for forward areas on active service. For this purpose a machine mounted on a one-ton chassis was designed. The same class of boiler was used, but there was only one chamber, of the same size and constructed in the same manner as the chambers of the large apparatus (Fig. 8).

Railway Van Disinfestors.

In 1915, when in Serbia, Lieut.-Colonel Stammers, R.A.M.C., used current steam from locomotives for disinfesting clothing which was exposed to its action in railway vans. Colonel W. Hunter brought the method into regular use in Egypt. The vans employed were of iron but otherwise of ordinary form with double closely fitting doors at the sides. The steam from the engine was conducted through the ordinary couplings that are employed in connection with the steam-heating of passenger carriages on railways, usually two vans being coupled to the engine. The steam main from the engine branched off into two parallel pipes about 4 ft. apart running along and upon the van floor so that they were away from the walls and left a gangway between them along the centre of the van. These pipes were of large size and the steam escaped from them through a double row of fine $\frac{1}{8}$-in. apertures 6 in. apart and bored along the upper arc of the pipe. A light but strong wooden framework, the supports of which rested on the floor close to the inner sides of the pipes, was built in the van to support three superposed shelves extending to the walls and running parallel to the length except where the doors opened. These shelves were intended for the clothing and were formed of slats 3 in. apart. The steam left the engine at 60 lb. pressure and consequently entered the chamber superheated, in great volume, and with much force. The heat of condensation was considerable and the penetration rapid, so that when the chamber was loaded with bundles of clothing, even to overfilling, the heat penetrated quickly into the centre of the bundles within five minutes of turning on the steam and the exterior surface of the van wall could scarcely be touched because of the heat. The air and steam apparently found means of escape through the narrow chinks at the door joists. A temperature of 100 ° C. was attained in the centre of the

largest bundles or a rolled mattress within thirty minutes of turning on the steam; lice and nits were killed and shrivelled, and potatoes placed in the middle of the bundles were cooked through in thirty to forty minutes.

The steps in the process of disinfesting the clothing of troops and prisoners of war by these railway vans followed the usual procedure of parading the men, a company at a time, at intervals of two hours. After removing all their clothes they remained dressed only in their greatcoats, caps, and boots, leaving behind articles of leather, helmets, caps, waterproofs, ground-sheets, and effects that included felt, glue, or rubber, which could not be treated in the disinfestor. Blankets and clothes tied up in bundles with their identity discs attached were then carried to the disinfestor van at a railway siding and stowed inside. Disinfestation lasted one hour from the time the doors were shut and the steam turned on. During that time the men could wash or bathe. After the bundles were returned the men took off their overcoats, with identity discs attached, and placed them in the disinfestor van.

The disinfestation of the overcoats took only fifteen minutes. The men then returned to camps, with their kits and overcoats disinfested, two hours from the time of their arrival at the disinfesting station. Two vans 18 ft. long could deal with the kits, greatcoats and two blankets each of 150 men in an hour, and four trucks with the effects of a brigade in two days. This system was claimed to be economical, for only one furnace was kept burning and the locomotive fetched its own fuel. Weight being no object, folding canvas screens and pipe systems could be carried and rapidly fitted to supply shower-baths. The clothing dries rapidly after steam is cut off and the number of trucks could be increased, so that when required a disinfesting train could deal simultaneously with a whole battalion drawn up on either side and delouse a brigade in a couple of days. As the train was of light draught an engine unfit for heavy military work could be used.

On the lines of communication in Mesopotamia Captain M. D. Mackenzie found the most economical and efficient method of disinfesting troops stationed on a railway was the use of steam released under pressure amongst the kit and clothing. A locomotive with two large closed metal vans constituted the disinfesting unit. The engine was coupled by copper steam pipes, fitted with taps, to both vans, and so arranged that each van could be used independently. The doors of the vans were fitted with flat rubber so as to ensure close fitting,

and shelves for kit were so arranged as to permit free circulation of the steam round kits. All other openings in the vans were closed except one at the far end of the floor of each van. An average pressure of 120 lb. to the square inch in the boiler was maintained during the time that steam entered the vans.

Each van was used alternately in order to waste no time of the personnel. The times for loading and unloading and the actual times for opening and shutting of the vans are given in the following table.

TABLE III.

Actual Times taken for the Loading, Disinfection, and Unloading of the Vans.

Van 1—

Loaded, 10 a.m. to 10.15 a.m.	100 kits and 200 blankets in 1½ hours.
Disinfecting, 10.15 a.m. to 10.45 a.m.	
Waiting until van was cool enough to enter, 10.45 a.m. to 11 a.m.	
Unloading, 11 a.m. to 11.5 a.m.	
Kits drying and issued to men, 11.5 a.m. to 11.30 a.m.	

Van 2—

Loaded, 10.15 a.m. to 10.35 a.m.	100 kits and 200 blankets in 1¼ hours.
Disinfecting, 10.35 a.m. to 11.5 a.m.	
Waiting for van to cool, 11.5 a.m. to 11.15 a.m. ..	
Unloading, drying and issuing to men, 11.15 a.m. to 11.30 a.m.	

Blankets were found to be dry fifteen minutes after the van was opened. The outside of the bundles of kit was completely dry in the same time. The inside was very hot and dried within a few minutes of the bundles being opened.

In the event of the engine running continuously day and night, one day in every six was required for oiling and overhauling. If the engine was used for shorter hours the necessary overhauling could be done at the end of each day.

The first step in the delousing of a unit was the complete disinfection of personnel working the train, in order to prevent the re-infection of the clothes during handling. This, together with the disinfection of 200 blankets and the necessary preparation of baths, steam pressure, etc., was easily completed in an hour.

The personnel then put on a complete overall covering for their protection against typhus-infected lice. It was found that lice readily passed through tightly rolled puttees, down the folds, whilst the ordinary uniform offered an easy means of infection by lice. To protect the body of the personnel, garments were made from sheets, with a cowl to cover the head

completely and tying under the chin, with closely fitting wrists, fastening down the back with a large overlapping piece and with trousers attached so as to form one complete garment. The whole garment was so made that a short length of closely placed buttons down the back sufficed to enclose the wearer

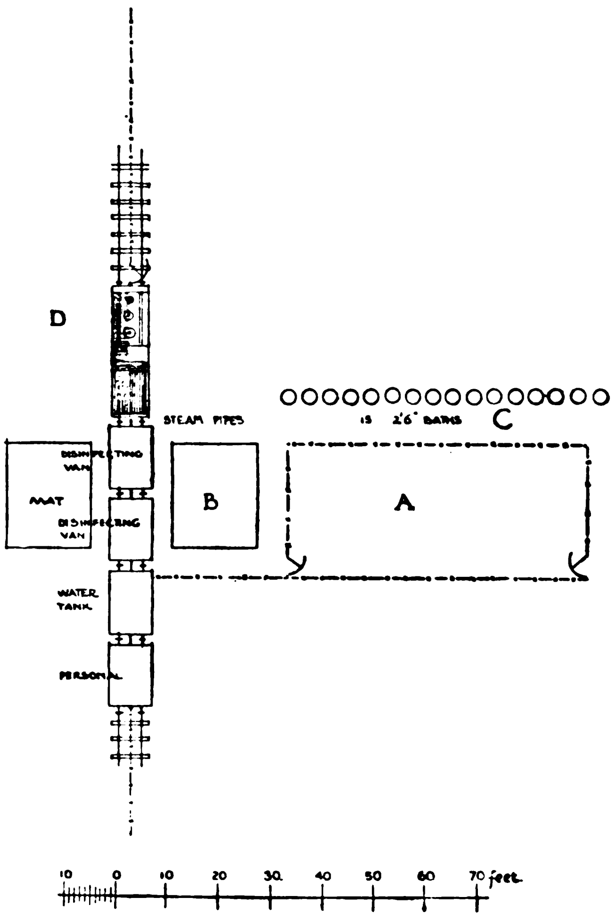


Fig. 9.—Arrangement of barbed wire enclosures for use with disinfecting train. First used at Ur, Mesopotamia.

completely, the man stepping into the garment; the trousers were made complete with feet. Gum boots were then put on, the interval between the leg being packed with cotton-wool soaked in paraffin or naphthalene. Thick rubber or leather gloves were finally put on and pulled well up over the wrists.

No case of either typhus or relapsing fever occurred in the personnel of the train when so guarded.

Two large areas, A and D (Fig. 9), were staked off on either side of the railway line and a good barbed wire fence run up. Twenty iron baths, C, were filled with 1 in 30 of a cresol-paraffin-soap solution. The train partially separated the areas A and D, the division being completed by barbed wire.

The unit to be disinfected fell in by platoons, or, in the case of natives, under their headmen, with their blankets and kits tied in separate bundles, each man's identification disc being fastened to his kit. Each platoon or group of twenty went up to the train successively and dumped their kits outside the van, on the reed mat, B. The group then proceeded to the baths where, under the supervision of a British sanitary non-commissioned officer, they bathed themselves completely with the emulsion for three minutes and then passed through the barbed wire gate in front of the engine to D, where two blankets were issued to each man, in which he wrapped himself until his kit was unloaded from the van. As each kit was unloaded the number on the identity disc was read out and each man received his kit, retaining the two blankets issued to him, his own being kept for the next party and issued to them during their wait.

At the base, as the troops were either proceeding to England for demobilization or to some other war area by ship, it was essential that means of disinfesting three to four battalions a day, independently of the weather, should be available. A building was therefore necessary.

The disinfesting station designed and equipped and eventually constructed on No. 9 Wharf, Magill, Basra, was the first disinfesting station in Mesopotamia to deal with large numbers of troops.

The actual disinfesting unit was a locomotive and vans running on a rail adjoining the building. Each unit was disinfested in groups of 150 under an officer or non-commissioned officer of the unit.

Each group entered the undressing room and stripped. Each man tied his clothes, uniform and kit together, and attached his identification disc to the bundle, which he passed, with his blankets, on to the counter. The kits were then loaded into the van by the personnel of the station and whilst steam was being passed into the van the locomotive proceeded down the rails parallel to the station, to the entrance to one of the dressing rooms, where at the end of half an hour the kits were

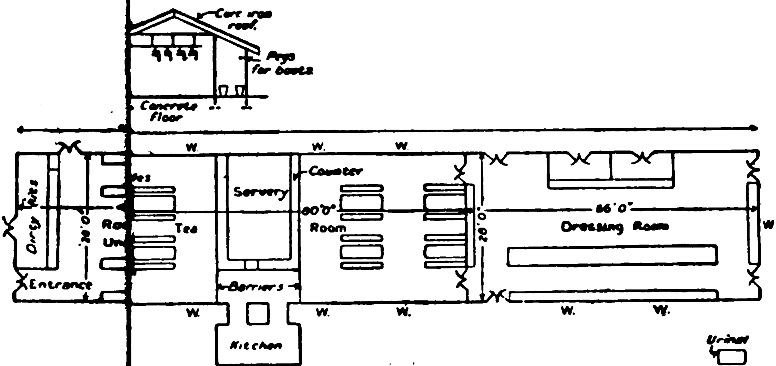
unloaded and re-issued. The group for disinfection in the meantime passed through the swing doors into the bath-room, where each man had three minutes in a hot cresol emulsion bath and two minutes under a hot shower, hot water being piped on from the boiler shown in the plan (Fig. 10). In the meantime the undressing room was occupied by a fresh batch of 150 men (Group 2). The first batch (Group 1) then proceeded to the drying room, where each man received a pair of pyjamas, a dressing gown and slippers. Group 2 now entered the bath-room and Group 3 was in the undressing room, while Group 1 was in the dressing room, where their kits were issued from the counter, a cup of hot tea was supplied to each man, and their pyjamas, dressing gowns and slippers were collected and returned by the station personnel to the drying room. As Group 2 left the drying room the men passed by a roped-off passage through the first dressing room to the second dressing room. Each dressing room received a batch alternately and worked in conjunction with its own disinfecting van outside. By this means, during the period of demobilization three to four battalions could be passed through the station every twenty-four hours.

Disinfestation by Hot Air.

Disinfestation, as distinguished from disinfection, can be readily effected by hot air provided an efficient circulation of air is maintained. This method of disinfestation was extensively studied during the war and many schemes were suggested. In 1915, as already stated, Professor G. H. Nuttall recommended the use of huts or possibly double-walled tents for the destruction of lice by hot air. Major H. Orr, C.A.M.C., first proved the efficiency of a makeshift hot-air hut built of corrugated iron at Shorncliffe, and later devised several types. One of these was subsequently modified by Captain Grant. The following is a description of this hut.

An Improvised Hot-air Disinfestation Hut.—The principle of hot-air disinfestation depends on the fact that exposure for thirty minutes to a temperature of 131° F. (55° C.) is lethal for lice and nits, but that in actual practice, and to give a good margin of safety, it is well to work at a temperature of 150° F. (65° C.).

The main problems in hot-air disinfestation by open coke fires are ventilation and heating. In ventilation it is necessary to obtain an adequate supply of air to keep the fires bright while at the same time conserving the heat in the hut. Concerning heating, the roof levels are very hot, 250° F. (120° C.), while the floor levels, to a height of from 2 to 3 ft., are warm but below lethal temperature. In a permanent hot-air hut an equable distribution of heat is possible by means of a fan, but in a makeshift erection where a fan is unlikely, unequal heating must always exist. A punkah is not effective.



gill.

Facing p. 362.

An experimental hut was made of wooden 3 in. by 3 in. joists, old 6 in. boards, ordinary coarse brown canvas, corrugated iron, scrap sheet-iron, wire from forage bundles, and two 5-gall. oil drums. The only articles used which were likely to be scarce in front areas were staples and door hinges, but effective substitutes for these could easily be obtained. The wood and canvas actually used were obtained from old targets in stock at certain barracks. The erection when completed was very rough and was only designed to ascertain whether the principles of construction were sound.

In dimensions it was 10 ft. long, 10 ft. broad, and 8 ft. high, and consisted of a framework of 3 in. by 3 in. joists and 6 in. boards supporting a double wall and ceiling of canvas. Twelve sheets of corrugated iron formed the roof, while old boards laid closely together formed the floor. Owing to the slope of the ground the floor was very leaky and had to be packed at the corners with paper. The door was a framework covered with a double layer of canvas. The air jacket between the walls was about 2 to 3 in. wide. For the reception of the braziers a shallow square pit, 4 ft. by 4 ft. by 6 in. deep, lined with scrap sheet-iron, was made in the middle of the floor. As the hut occupied a high and exposed situation between two other buildings and was subjected to high winds and eddies, four corner wire guy ropes acted as moorings, while the windward side was given some slight protection by a rough fly-sheet made of blankets. The braziers were made from 5-gall. oil drums by cutting a longitudinal sheet of metal 8 in. broad from each drum and riddling, by a punch and hammer, the remaining "cradle" with 85 holes ¾ in. to 1 in. in diameter. As the ends of the drums were soldered they had to be riveted. For supporting the material for disinfestation 20 wires were stretched, 6 in. from the ceiling and 6 in. apart, from side to side, and 10 more were stretched similarly from above the door to the opposite wall, crossing beneath the transverse wires. The ends of the wires were secured by staples or nails driven into the top joists. Each wire held two blankets, one at each end, and the total load was 60 blankets.

The blankets were hung about 6 in. from the ceiling, end-on to the fire, with one-half of their length draped on either side of the wire. They were then puckered so that they hung in loose folds. This was preferable to hanging them double or four-ply, as the extent of surface directly exposed to the heated air was thereby increased. Self-registering thermometers were placed in various situations one at each corner of the hut, or farthest away from the fire, in a fold on a level with the lowest edge of a blanket and 3 ft. 6 in. from the floor. Also, a large ordinary thermometer was inserted through the door in a similar position. These self-registering thermometers showed the highest temperatures to which the blankets at these positions were subjected. Readings were also taken at higher levels. The fuel used was coke—20 lb. in each brazier. The braziers were filled with the fuel, placed on two bricks in the open, and kindled, and when the coke was brightly incandescent and the fire approaching its best, each was carried on a long iron rod and placed on and between two bricks in the pit in the centre of the floor. A deflector formed of a sheet of iron about 3 ft. square was hung, by means of a wire, above the braziers on a level with the lower edge of the blankets in order to deflect the heat.

The following is a typical record of the conditions under which disinfestation in this hut was effected :—

Outside temperature and weather	66° F. (19° C.); very windy, causing bad eddies round the hut.
Load	60 blankets.
Time to reach lethal temperature–150° F. (65° C.)	45 minutes.
Time of exposure at lethal temperature (reading taken at lowest edge of blanket).	30 minutes at 150° to 171° F. (65° to 77° C.).

Maximum temperature reached at lowest edge of blanket.	171° F. (77° C.).
Total time of heating	1¼ hours.

The readings of the three inside thermometers at the end of disinfestation were 162° F., 162° F., 160° F. (71° C., 71° C., 70° C.). Thermometers at the upper level of the blankets recorded 250° F. (120° C.), while those in the centre gave 194° to 212° F. (90° to 100° C.). In no cases were they exposed to the direct rays of heat.

Only once was the hut used in a damp condition after rain. It was not soaked, however, and the dampness increased the time for raising the temperature to the required height by 15 minutes only.

The method of hanging two tiers of blankets was not successful; it was found that by using the upper tier only the time of heating was less than half the time required when two tiers were used. Consequently nothing was gained by extending the time in order to raise a lower tier to a lethal temperature.

The temperatures reached in this improvised hut were as high as those obtained in an adjacent permanent hot-air hut. After the improvised hut had been tested for a month the following data were arrived at:—

Time of loading 60 blankets by 2 men	½ hour.
Time of loading 60 blankets by 3 men	¼ hour.
Time of exposure in hut, including ½ hour at 150° F.; first operation of day	1¼–1½ hours.
Time of exposure in hut, including ½ hour at 150° F.; subsequent operations	1–1¼ hours.
Time of unloading by 2 men	¼ hour.
Time of unloading by 3 men	5 minutes.
Number of operations, including loading, heating, disinfestation, unloading with 2 men working 10 hours daily	4 to 5.
Number of operations with 3 men working 10 hours daily	5 to 6.
Number of blankets daily with 2 men working	240 to 300.
Number of blankets daily with 3 men working	300 to 360.
Amount of coke consumed in each operation	20 lb.

With skilful firing the time of each operation can be reduced to one hour. Loading should occupy as little time as possible in order to prevent the undue cooling of the hut as well as to obtain the maximum number of operations each day.

The situation of the hut should be as sheltered as possible and on the ground level. A floor of earth is too cold, and old boards, sheets of corrugated iron, or ration tins beaten flat, should be laid to conserve heat and to prevent draughts. For the same reason the lengths of canvas forming the walls should overlap widely to the extent of 6 in. or 8 in. Hinged doors are not absolutely necessary, as the entrance and the exit on the wall opposite to the entrance may be closed during disinfestation by a wide double roll-curtain weighted at the bottom and fastened at the sides. In securing the wires long nails may be used, but a preferable plan was to run 2 in. by 2 in. joists along the walls at the required height of 7½ ft. from the ground and twist the ends of the wires around them. The wires could be twisted around the upper main joists but they perforated the canvas. Wood, when more plentiful than canvas, could be used for making the walls, but in any case an area of canvas equal in size to a door should be placed in the middle of each wall. If the hut is to stand alone a roof of canvas is not sufficient protection against rain as it sags too much and is too absorbent. Tarpaulins or corrugated iron would serve for roofing, while partially destroyed barns or cottages made convenient shelters. When the hut could be placed in the centre of a large marquee or roofed building a receiving space for verminous articles and a delivery space for articles disinfested could be arranged, and heating would be easier on account of the protection against weather.

As a hot-air disinfestor depends for its success on large general ventilation surfaces and the presence of an air jacket, it should be placed so that air has free access to it. Thus, merely to roof in four walls of bricks or stone would fail to give the necessary temperature. A separate canvas erection is necessary, but the surrounding walls would be a great protection against wind and cold. The object of sinking the fire in the floor is to obtain as much heat as possible at the lower limits of the articles for disinfestation.

The heating depends on coke, and for the first operation the two braziers should be filled with about 20 lb. of coke each. After each operation the ash should be shaken out and fresh fuel added. If for some reason the heat required is not being obtained quickly enough it may be necessary to replenish the fires in the hut. Ordinary care in firing, however, will obviate the necessity for this.

An ordinary bath thermometer should be placed inside the "window" in the door and on a level with the lower edge of the material. Six fire-buckets, three filled with water and three with earth, should be provided.

Three men are sufficient personnel for the actual processes of disinfestation.

The articles capable of being exposed in each operation were 60 blankets or approximately 100 suits of khaki, or 200 pieces of underclothing or 60 great-coats. They had to be hung loosely as far apart as possible and end-on to the fires. Tunics and trousers should be turned inside out and, as with underclothing, should be hung on wire hooks. A point of importance is that the hot-air process, unlike steam, does not injure the leather strappings of riding breeches or leather equipment.

A hut of more permanent construction, Orr's Model B modified by Grant (Fig. 11), had double walls of uralite, or of uralite inside and corrugated iron outside, in place of canvas. Fresh air inlets were provided by two 6-in. pipes running beneath the floor and opening beneath the centre of a large brazier. A ventilator in the roof prevented the air that is confined between the roof and the ceiling from becoming over-heated. Two hot-air outlets were placed high up in the walls. Two tiers of bars or thick wire ran at right angles to the length of the hut, leaving a clear passage of 4 ft. 6 in. wide down the centre. The brazier was placed in a well sunk 6 in. to 12 in. below the floor level; the floor of the well was made of fire-clay or fire-bricks. The floor of the hut was of concrete or of coke breeze covered with ¾-in. flooring and protected by a sheet of iron opposite the door to guard against falling embers. A hut of this kind measuring 14 ft. by 14 ft. by 9 ft. high, or 1,764 cub. ft., containing 60 iron rods 4 ft. 8 in. long in tow tiers, could treat 300 blankets at one time, each blanket being folded lengthways over a rod with the blankets of the lower tier not hanging closer than 1 ft. from the floor, as the lice may survive near the floor level. It took two men about twenty to thirty minutes to load the rods with blankets. The exposure was timed from the moment the thermometer, 4 in. above the floor, reached a temperature of 80° C. At the end of the exposure, after the doors are opened and the brazier carried out, the chamber is ventilated and the contents removed, the process occupying

about twenty minutes. The men entering the hut must be warned not to inhale the coke fumes. The floor of the hut should be washed down with cresol solution in order to destroy any lice that may linger upon it.

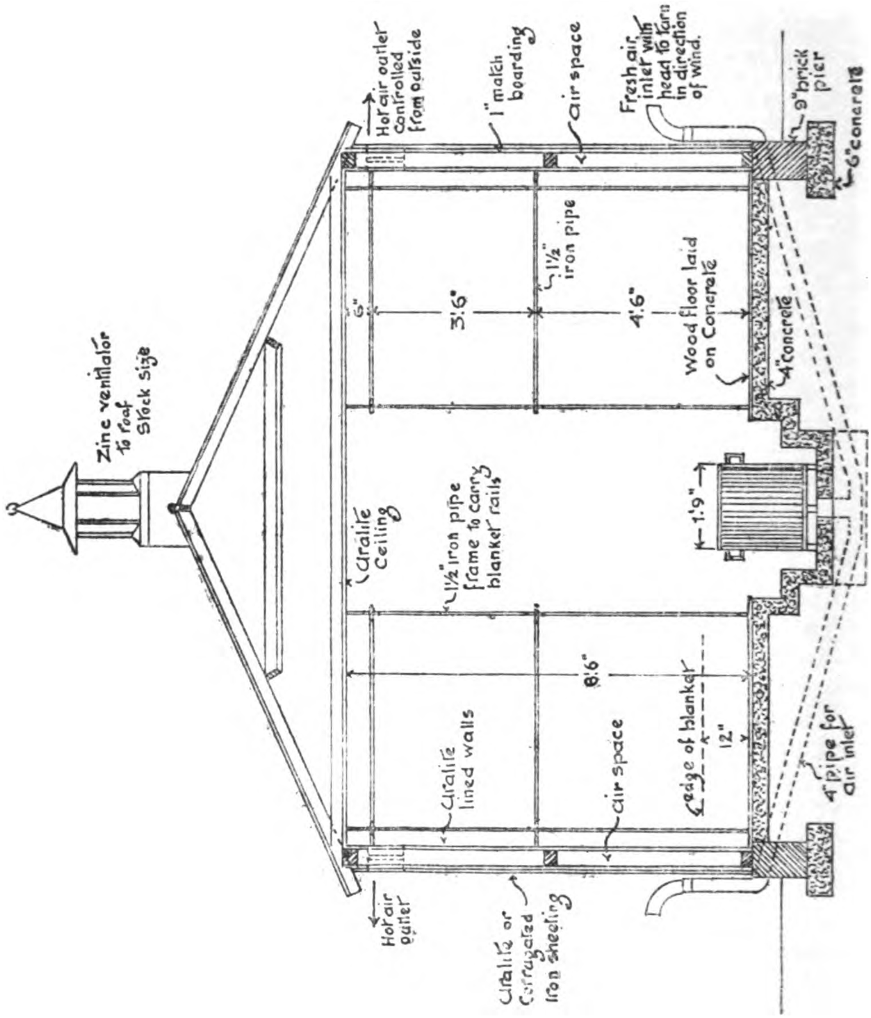


Fig. 11.—Hot air disinfestation hut. (Orr, Model B, modified in details by Grant.)

Captain Jacobs also designed a hot-air hut. The chamber measured 15 ft. by 15 ft. by 7 ft. in height. The space between the double walls was filled with sawdust and the floor was cemented. It was heated by a cast-iron stove having a heating

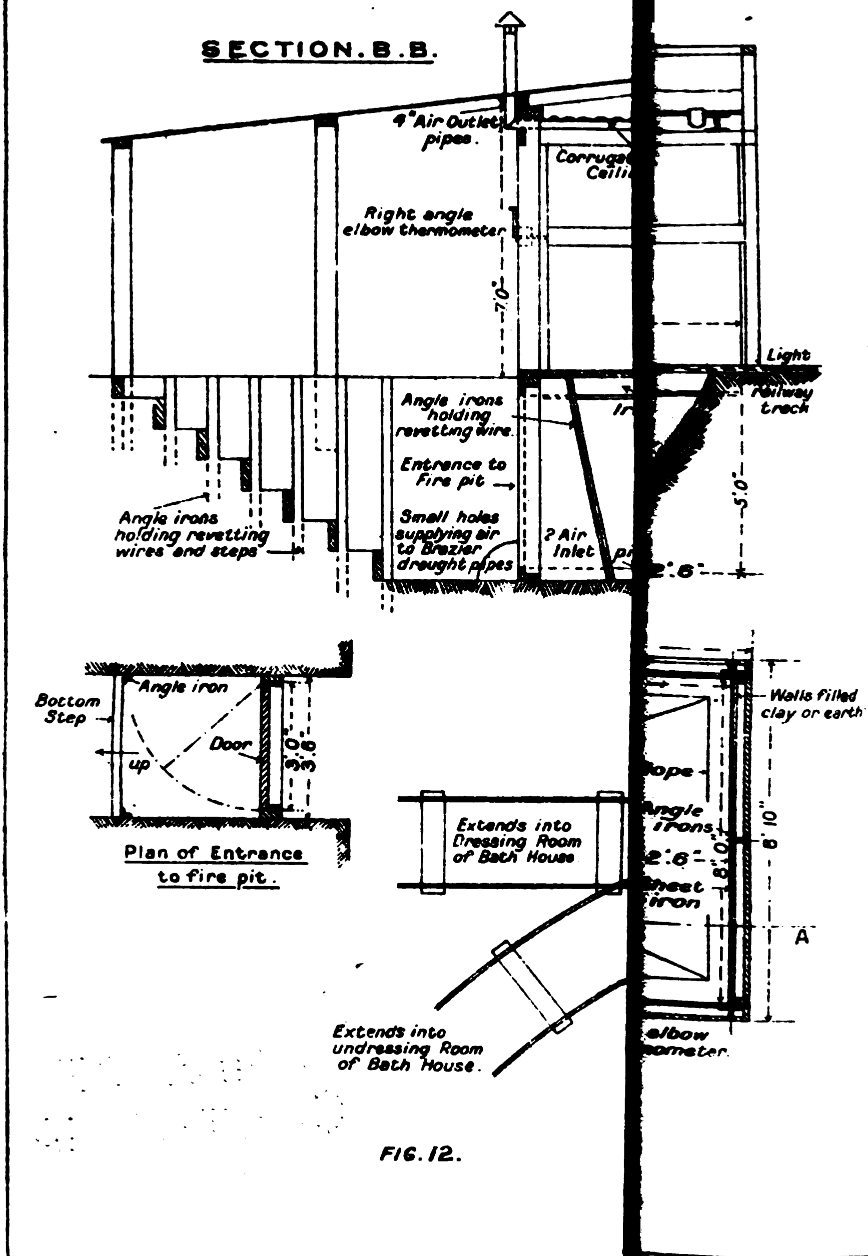
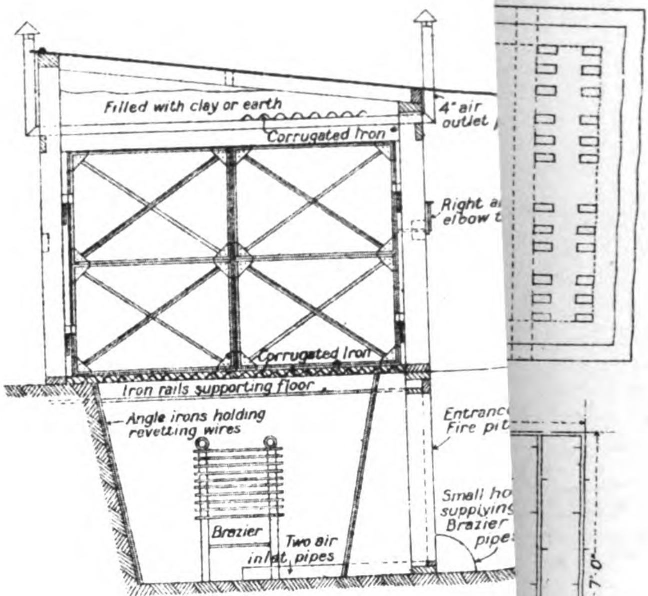

SECTION. B. B.
4" Air Outlet pipes.
Corrugat Ceili
Right angle elbow thermometer
7'0"
Light railway track
Angle irons holding revetting wire.
Entrance to Fire pit
Small holes supplying air to Brazier draught pipes
2 Air Inlet
Angle irons holding revetting wires and steps
5'0"
2'6"
Angle iron
Bottom Step
up
Door
Plan of Entrance to fire pit.
Walls filled clay or earth
Extends into Dressing Room of Bath House
Angle irons
2'6"
Sheet iron
8'0"
8'10"
A
elbow
Extends into undressing Room of Bath House.

FIG. 12.

C



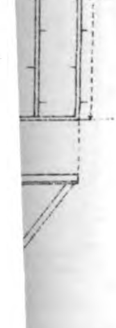


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FIG. 13.

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surface of 1 sq. ft. per 100 cub. ft. A perforated iron sheet was placed above the stove, leaving a 3-in. space all round; it acted as a radiator. The outside air came in by two pipes, at the sides of the fire-box, which passed through the combustion chamber and delivered the heated air into the chamber by openings 15 in. above the floor level. After circulating in the chamber the air passed to four flues opening into the chamber but 7 in. from floor level and situated in the cavity of the double wall, and thence to a main exit shaft in the roof measuring 3 ft. across and twice the height of the building. The chamber had doors on opposite sides opening into corresponding rooms serving respectively for the reception and delivery of the articles. A number of racks running on top rails held the articles, and to avoid loss of heat they were not all pushed in at one time, but in succession, the door being opened and shut as quickly as possible. Several of these huts were in use in France and acted well when properly handled.

The hot-air hut used in connection with bathing establishments and for disinfestation during demobilization was a model designed by Major Orr, C.A.M.C., the details of which may be gathered from Figs. 12 and 13. A full description of the hut was issued by the D.G.M.S. of the British Armies in France in the form of a circular memorandum.

An improvised hot-air disinfestor which was used somewhat extensively in France and in other theatres of operations during the latter months of the war was that known as the Russian pit or dugout disinfector. The type used by Major W. E. C. Lunn, R.A.M.C., in Salonika is shown in Fig. 14. The construction and use of this pit was brought to the notice of the A.D.M.S. (Sanitation) by the D.D.G.M.S. at G.H.Q. early in 1918, and he was asked to make experiments in order to test its efficacy.

A site consisting of sandy loam was selected and in the ground a chamber 8 ft. long, 6 ft. wide and 7 ft. high was dug. Access to the chamber was by means of a doorway about 2 ft. wide and 7 ft. high at one end of the chamber. An approach to the entrance was cut in the ground.

The chamber was roofed in with wooden beams and corrugated iron over which a layer of earth was spread.

The doorway of the chamber was closed by a sheet of corrugated iron sliding vertically in grooves cut in the wall at the entrance of the chamber.

Two simple stoves made out of oil drums were placed in the chamber, one in each of the far corners, with flue pipes

leading vertically upwards through the roof to about 2 ft. above the layer of soil on the roof.

The temperature of the air within the chamber was observed by means of a thermometer suspended in the centre of the chamber 1 ft. from the ground. The thermometer was illuminated by means of an electric lamp and the temperature could be read off through a small glass window inserted into the sliding door of the chamber.

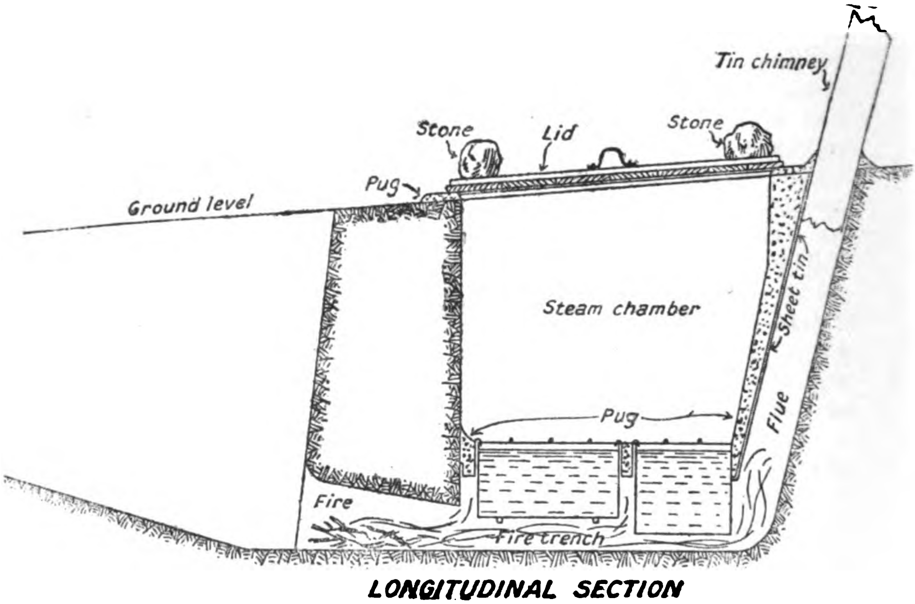

Fig. 14.—Russian pit disinfestor.

For experimental purposes folded sacks were used instead of garments and the temperatures attained within the folds of the sacks were determined by means of glass tubes containing substances which melted at temperatures varying from 51° to 85° C.

In the experiments, the door was opened at the end of thirty minutes and the sacking with temperature recording tubes was removed. It was found that the temperature attained within the folds of sacking in the centre of the room and also within the sacking near the door had melted the contents of all the tubes except the highest, that is to say, had risen to above 77° C. but not so high as 82° C. None of the tubes against the wall were melted, so that the temperature there did not

reach 51° to 53° C. This was to be expected, as earth walls are damp and cold and readily cool the air in contact with them.

In other experiments in which the tubes were placed in paper envelopes, none of them were melted even though they were not wrapped in sacking, so that a covering of paper sufficed to prevent their attaining a temperature of over 51–53° C. within half an hour, notwithstanding the fact that the surrounding air was at a temperature of over 90° C. A lousy shirt hung loosely in the chamber was nevertheless disinfested, all the lice being killed.

Several experiments were conducted, and the conclusions drawn from them were that a chamber of the kind described had certain inherent defects. It could, however, serve for disinfestation in an emergency. With the clothes turned inside out and suspended loosely at a distance from the walls of the chamber with ample air space between each article, the accommodation of the chamber would be somewhat curtailed, but it would nevertheless be useful in circumstances where a more efficient type of disinfestor could not be improvised. In fact, Russian pits were extensively used in France and other theatres of war, and when suitable precautions were taken and garments were suspended at some distance from the walls of the pit they gave satisfactory results.

A portable hot-air disinfestation hut (Fig. 15) was built by No. 57 Sanitary Section for the Fifth Army in France. It

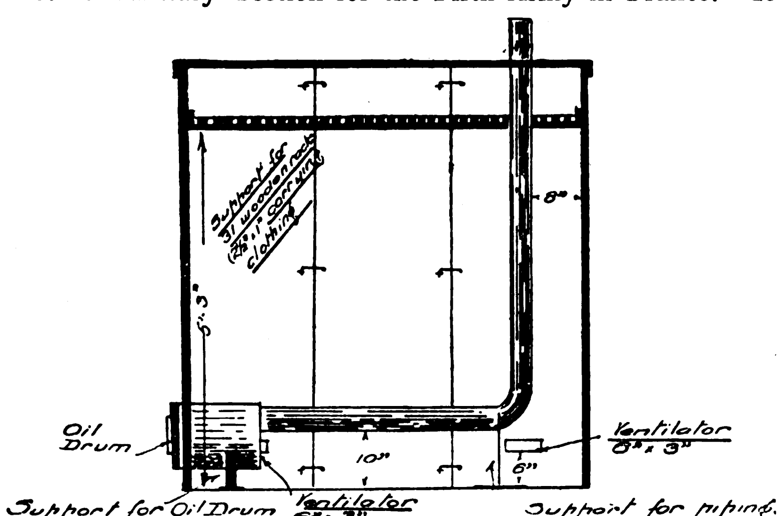

Fig. 15.—Portable disinfestation chamber.

was made in sections and could be erected in a few minutes; it was carried on a box-car, motor ambulance car, or general service waggon. The chamber was 6 ft. by 6 ft. by 6½ ft. and was constructed of timber (2½ in. by 1 in.), lined inside and outside with tin obtained from a ration dump. It was heated by a stove made out of a cresol drum, the stove pipe being obtained from an R.E. dump. Iron dowels were inserted between the various sections to hold them together, and the roof was formed in two parts. The chamber was provided with racks and rails from which the articles to be disinfested were hung. Ventilators were inserted in the walls to ensure a current of air through the chambers. Even with a wood fire a temperature of 65° C. was obtained inside the hut in ten minutes and a temperature of 89° C. in fifteen minutes. Sixty-two blankets were disinfested at one operation.

The total weight of the hut was only 4½ cwt. and none of the sections was too heavy for one man to carry.

Disinfestation of Huts, Billets and Transport Vehicles.

When a unit evacuated barracks or hutments it was important to see that all blankets and bedding were disinfested before re-issue, the rooms thoroughly cleaned, and the floors sprayed or scrubbed down with insecticide solution.

In billets the floors should be similarly treated and the walls, when possible, whitewashed. Special attention should be given to cracks between the floorboards. A good plan was to put up a notice in billets for the men to read, the notice stating briefly the essential facts which the soldier should know regarding the methods of combating lousiness.

Railway carriages under ordinary conditions could be disinfested by scrubbing down all washable parts with insecticide solutions, afterwards drying off the ironwork to prevent it rusting. Covered trucks could be treated with a steam jet fed from the engine.

Transport waggons should be disinfested in the same manner as railway carriages.

Articles that suffer from exposure to heat, especially groundsheets and waterproof coats containing rubber and leather, which, however, as already noted, is uninjured by dry heat at a temperature of 65° C., should be treated with insecticide solutions, and afterwards hung up to dry. Furs may be disinfested by dry heat at 70° C. or by exposure for twenty-four to forty-eight hours in hermetically sealed containers in an atmosphere saturated with naphthalene.

Other Methods of dealing with Lice.

Infested clothes, when valueless, were burnt. Singeing, sun-baking, ironing of infested clothes or pressing them on a stove-heated metal plate or by wrapping them round tins containing boiling brine, were other methods employed for dealing with clothing. By holding the clothing against any piece of heated iron or hot stones from a camp fire, or close to a hot fire, many of the lice will be killed or dislodged. Baking ovens are useful for this purpose.

The essential points are that hot air penetrates rapidly into fabrics that are loosely hung and amongst which it can circulate, and that stagnant hot air penetrates very slowly into tightly packed fabrics. These rudimentary facts were established by comparative experiments from the early days of disinfection, but they were constantly ignored, with the result that failures in practical disinfection with hot air or steam at atmospheric pressure were frequent.

Barrels or ordinary packing cases through which hot air circulated served as fairly efficient lice disinfestors. In some cases the heat was obtained from a pipe traversing the disinfestation chamber from a flue beneath the floor.

Practical experience showed that in all structures built on this plan, it was necessary to guard against the danger of scorching articles placed in too close proximity to the heated iron plate at the bottom of the box.

Insecticides.

The mode of action of insecticides varies according to the nature of the remedy. Physical effects alone doubtless explain the action of indifferent fluids, oils, or fats, since these occlude the spiracles in the active stages and the opercular orifices of the nits. Direct toxic effects are induced by various mineral or organic vapours, operating either in solutions in which the insects are immersed or pervading the atmosphere in which they are confined. Certain substances, such as oil of anise, cloves, eucalyptus and naphthalene were proved by experiment to exert a repellent action on lice, but in practice the evidence indicated that hungry lice would attach themselves to man and feed on him in spite of repellents. In fact, Nuttall, to whom much of the information on the subject is due, believes that when these substances protect man they act in the main as insecticides.

At the outbreak of war there was comparatively little exact knowledge as to the efficacy of insecticides. Preparations by the hundred were sent to the War Office, but beyond the statements of the makers there was little evidence produced to guide the authorities in the selection of the most suitable remedies. In 1914 experiments were made at the Royal Army Medical College on the lethal and repellent actions of various preparations; eventually a powder, composed of naphthalene 96 parts, creosote 2 parts, and iodoform 2 parts, was devised for use and generally known as N.C.I. powder. About this time Professor Lefroy suggested the use of a proprietary preparation called vermijelli, which was stated to consist of bottom oil (cracking point 600° C.) 20 parts, Texas fuel oil (specific gravity 0.86, boiling point 200–350° C.) 50 parts, pure soft soap 30 parts, water about 6 parts. A leaflet on the prevention of lice was issued by the War Office in 1915. N.C.I. powder was recommended to be dusted on the underclothing, and vermijelli to be rubbed into the seams of the coat and trousers of soldiers.

Lieutenant Peacock tested many insecticides under field conditions and found the N.C.I. powder to be the best all-round insecticide. He advised dusting 2 oz. upon the shirt and trousers every four days. From observations on men he concluded that the effect of keeping off lice lasted from three to five days; he considered it to be useful in the trenches, and observed no ill-effects on himself and three men after using it for a week, except that it produced itching or smarting at the fork, in which case it should be replaced by an ointment such as vermijelli.

Mr. Bacot, the entomologist to the Lister Institute, carried out for the War Office a large number of experiments on insecticides. The scheme followed in the trials was to arrange the conditions on as nearly natural a basis for the insects as was consistent with their control and strictly comparative results, particular care being taken that the insects should have the opportunity of feeding during the experiments.

The net results of the trials suggested that the diffusive effects of all the substances tested, except possibly naphthalene, was so slight as to reduce them all to a common level of contact remedies. Viewed in this light it would be necessary to impregnate or thoroughly dust underclothing with them to obtain any effect. Naphthalene if used in a form in which garments can be impregnated was found to be an almost perfect remedy, as it killed quickly. The chief objection to its use was

its rapid evaporation. Most of the trade preparations were found to be of little use. Mr. Bacot did not obtain good results with the vermijelli. He found that flannel soaked in a 5 per cent. solution of an emulsion of crude carbolic acid and soap in warm water was effective; the emulsion consisted of 45 to 50 per cent. of soft soap combined by heating with 50 to 55 per cent. of crude carbolic acid. He suggested that shirts and underclothing should be impregnated with 5 per cent. of the emulsion in warm water. After dipping, the garments should be wrung and thoroughly dried before wearing. Shirts so treated were found to be pediculicidal for six to seven days. Experiments were carried out at Sandwich with 98 men to determine the degree of irritation of the skin produced be wearing the shirts. After the first day only 2 men showed irritability, after the second day 7 men, after the third day 3 men, after the fourth day 4 men, after the fifth day 3 men. After the sixth day all the men were free from any signs of irritation. Trials were then made in France, but the administrative difficulties of treating men's shirts were considerable, and though the shirts were undoubtedly palliative the results obtained were not considered of sufficient value to justify the general use of the method.

Similar results were obtained with light cotton undershirts impregnated as before and worn beneath flannel shirts. The cotton undershirts were worn by 100 soldiers in France under campaigning conditions; after a period of eight days spent in the trenches the men were bathed and had a clean issue of underclothing. The general conclusion was that the garments did not clear the men of lice nor kill the lice though they undoubtedly diminished the intensity of the infestation. In view of these results the expense of supplying impregnated shirts was not considered to be justified.

As a result of many experiments made in conjunction with Lieut.-Colonel Monckton Copeman, then in charge of the hygienic department of the Royal Army Medical College, Mr. Bacot recommended the use of a paste made with crude, drained, *unwhizzed* naphthalene from modern coke ovens, that obtained from gas plants being far less efficient. The naphthalene was ground fine and then mixed into a paste in the proportion of 3 or 4 parts naphthalene to 1 part of soft soap. It formed an exceedingly efficient insecticide and could be used for smearing between seams in tunics or breeches. A single application should be effective for about one week. On undergarments it should be smeared more lightly over as wide

an area as possible. Light applications should be effective for one to two days. The paste killed lice within two hours of application. It was not suitable for smearing on the skin, and should not be applied heavily where collars or cuffs tend to chafe the skin. When used by the troops it was put up in 2-oz. or 4-oz. tins with close-fitting lids, and applied by rubbing with a piece of rag. Every man going into the trenches received a tin, and a stock was kept at regimental headquarters so that the tins could be replenished. The distribution of the insecticide was under the supervision of the regimental medical officer.

The use of the insecticides as a whole, either upon the person or clothing, is always a confession that men cannot be kept free from lice by direct means, in consequence of the lack of preventive measures, which is commonly due to infested men or infested clothing escaping attention in various ways and transmitting vermin.

General Instructions in Lice Prevention.

As a first step in combating lousiness it is essential to teach men what lice are and to tell them of the harm that lice may do. When this has been impressed upon them they should learn the simple methods of mitigating the scourge. The individual soldier may at any time be thrown on his own resources, and, as the experience at Wittenberg showed, he is liable to be made a prisoner and to suffer from gross neglect at the hands of the enemy.

Nearly all forms of treatment designed to kill lice upon the person fail to clean an individual at one application unless the individual is only slightly infested, the reason being, as already pointed out, that nits commonly survive the application of insecticides. Most remedies act in the first instance by immobilizing the active stages and thus facilitating their removal mechanically; other remedies undoubtedly kill if they are given time to act. Greases and oils of all kinds are inimical to lice because they asphyxiate them, but the nits may survive after these substances are absorbed by the skin or are lost by evaporation. Many remedies have been recommended for treatment of lice.

Chloroform water (5 in 1,000) rubbed on the infested scalp or other hairy parts of the body quickly immobilizes *Pediculus* and *Phthirus* and renders it easy to remove them with a comb or by shaving. It temporarily immobilizes the active stages, but leaves the nits unaffected.

Petroleum has been extensively used as a spray to the body and as an application along the seams of clothing in destroying body-lice. The treatment has to be repeated. It has also been used effectively for crab-lice, and is a commonly employed remedy in many parts of the world for head-lice. In the latter case the hair should be well wetted with petroleum and the head bandaged with an air-tight covering for some hours or overnight, the head being well washed with warm water and soap upon the removal of the bandage. Owing to the irritation it may produce on the skin it is frequently mixed with an equal volume of vaseline or olive oil. In either case the application has to be repeated on two or three successive days or nights, especially in the case of badly infested heads. The soaping and washing in hot water have to follow each application. Applied but once it is a palliative measure only. The olive oil has the objection that it soils articles of clothing and any other non-irritating oil will serve as well.

Rectified oil of turpentine does not irritate the skin and does not soil. It may be sprayed on the head, which is afterwards covered with a bandage overnight. It kills lice as efficiently as petroleum and will probably be found more effective against nits. Its application should also be followed by washing.

Vinegar, or 10 per cent. solution of acetic acid, greatly facilitates the removal of nits from the hair because they can without difficulty be slipped off by means of a fine comb or between the fingers when these are run along the hair from base to apex. It dislodges lice but does not kill. It does not dissolve the chitinous tube of the nit that surrounds the hair, but appears to act by rendering the hair slippery so that the tubes glide easily along them.

Mercurial preparations should be used with caution. There is no evidence that they offer any advantages over other remedies. The use of blue ointment should be debarred. Ammoniated mercury ointment (5 per cent.) may be applied once a day for a week for crab-lice if shaving is not practised. Sublimate vinegar (0·2 per cent. $HgCl_2$ in ordinary vinegar) is applied after soaping and washing the head well. The skin should be merely moistened with this preparation and not rubbed as irritation is easily produced. If the skin smarts this is due to lesions, which should be protected by vaseline. One application may suffice in mild cases of head-lice and crab-lice. Calomel pomade (HgCl 1 in 20 vaseline) may be applied, where scratches are present, for head-lice and crab-lice. Oleate of mercury and ether (oleate 5 per cent. and ether equal parts) may be used.

Crusts on the head are best removed with the aid of carbolized oil. Mercuric oxide ointment, red or yellow (5 to 10 per cent.), may be applied in a preparation containing 1 oz. of ammoniated mercury, ½ oz. of oxide of zinc, and ½ oz. of silicate of magnesia. This preparation is suitable for application to the skin, or to seams of clothing, the latter being afterwards ironed. It is useful in the treatment of infestation by the body-louse, especially in wounded men who cannot be adequately cleaned by direct means.

For ordinary treatment of crab-lice, shaving of all parts where there is hair, if thoroughly carried out, is sufficient, as in the absence of hair crab-lice cannot exist on man.

When crab-lice and their nits occur on the eyelashes they are best picked off one by one with fine forceps after anointing the parts with balsam of Peru, or the lids may be smeared with a 2 per cent. mercuric oxide ointment applied daily for a week in order to kill the active stages as they emerge from any of the nits which resist the treatment.

Insecticide solutions which are used for steeping verminous effects, washing down floors, and so on, may also be applied to the hair or skin. Of these the best are 2 per cent. solutions of cresol, lysol, or carbolic acid. All three are commonly mixed with soap, which merely acts as a cleaner, not as an effective insecticide. Their efficiency, as tested on nits, showed that cresol solution killed the nits in twenty-five minutes and lysol in 1½ to 2 per cent. solutions killed them in five minutes.

As a result of the various methods of disinfestation described above the following instructions were drawn up with a view to summarizing the means of preventing infestation with lice :—

1. Soldiers should be inspected once a week in all circumstances at the same time as when examined for scabies. Unremitting attention is required.

2. Men who are found to be verminous should be disinfested as soon as possible so as to check the evil at the start.

3. All soldiers should receive a bath once a week, or at least once in two weeks, the bath being followed by a change of underwear.

4. Where men are prone to become verminous disinfestation should be practised every two weeks.

5. Disinfestation should be applied to all of the men who live in close association, none being allowed to escape the process. Every article of clothing pertaining to every man, including his cap, greatcoat, blankets and pack, should receive treatment. Various articles which are the soldier's personal property may harbour lice.

It should always be remembered that not only crab-lice but also *Pediculus* may infest the hair over different parts of man's body, therefore, unless such nits and lice are removed, a man may re-infest his clothes.

6. Bathing should be controlled to see that it is efficiently carried out, the man being inspected after the bath and before being allowed to dress.

7. The larger the number of men disinfested at one time the better, since there will be fewer verminous companions about, through contact with whom they may subsequently become re-infested.
8. As far as circumstances will permit the disinfested men should be kept apart from the infested.
9. Soldiers proceeding to the front or returning thence should in each case be examined before they are allowed to mix with other men. A single lousy individual may infest many others with whom he associates.
10. The hair should be kept cropped short, especially at the sides and back of the head.
11. The personnel employed in disinfesting men should be permanent, specially instructed, and trustworthy, to ensure efficiency and continuity in the established methods of treatment.
12. The personnel should have unlimited facilities for bathing, be subject to inspection and control once a week, and keep their hair close cropped. They should wear protective clothing whilst engaged in their duties, and be employed on the clean or unclean side of the establishment at one time only.
13. Clean or disinfested effects should not be stored even temporarily where infested articles have been kept. Such effects should be strictly kept apart.
14. Carts and transport wagons used for the conveyance of infested articles are not to be employed for the transport of clean effects without being previously disinfested.
15. The most reliable means of destroying lice and nits are by hot air or steam. Insecticides as ordinarily applied to men are merely palliative, because they fail to destroy the nits.
16. As the dead nits are cemented to the fabric by the mother insect they necessarily have to be removed mechanically either by carding brushes or with the edge of a knife or finger-nail; the latter operations can be performed by the soldier himself.

Disinfestation in North Russia.

All towns and villages of any size in North Russia had a public bath-house, and in many a more or less modern current steam or pressure steam disinfecting machine was found installed as part of a bath-house. The average Russian in this region looked forward to and enjoyed his weekly bath and frequently took advantage at the same time of having his clothing sterilized and washed. At the base, therefore, means for disinfection were available locally and the troops at once took advantage of these opportunities.

In the forward areas, however, although many of the villages had bath-houses, none had disinfecting apparatus.

The force was well supplied with apparatus by ordnance services, as many as twelve Thresh disinfectors and a number of the portable box pattern being available at the beginning of 1919.

The Thresh machines were allocated to different situations at the base, for example, to No. 85 General Hospital, No. 53 Stationary Hospital, and No. 82 Casualty Clearing Station. The American troops had several, and a large Manlove and Alliott's machine, which had been sent out to undertake the

disinfection of horse-rugs and blankets, was allotted to No. 125 Sanitary Section. Two Thresh machines were sent up-river on barges in November 1918, a few days before the River Dvina was closed by ice, to supply part of the requirements of the river force and the river lines of communication. One was installed at Beresniki and the other at Yemetskoe. Another was forwarded by rail to the headquarters of the railway force at Obozerski. The box pattern disinfectors were distributed to outlying posts such as Onega.

But this available ordnance equipment did not by any means meet the needs of the entire force. The large number of small detachments, each of which had to be catered for individually in this respect as in all other sanitary matters, made a demand on the sanitary material with which, in the early stages of the campaign, it was impossible to cope. Thus, by force of circumstances, the forward troops suffered.

Circulars with explanatory diagrams were issued to all detachments indicating methods of making and using "Serbian" barrels as disinfectors. Later at the base the serviceable and invaluable "vodke" drums were adapted and remodelled in considerable numbers as disinfectors and distributed where most required. The top of the drum was carefully cut out and a close-fitting wooden lid substituted. The under portion of the lid was fitted with hooks on which to hang clothes. The drum was 4 ft. in depth. A movable wooden grid was fixed inside about a foot from the bottom. Water was poured in to reach a height little short of the grid and the whole placed over a rough bricked fireplace. The drum could hold comfortably twelve blankets or six suits of service dress in such a way that full penetration was possible. Detailed instructions to ensure proper use of the apparatus were issued to all concerned. Diagrams indicating the method of arranging the working of ordinary "Serbian" barrels in batteries were also issued.

At the base it was possible by using a Russian bath-house in which a disinfector was installed to disinfest a large number of men in a day. Archangel, Bakharitza (Fig. 16), Solombola, Smolny, and Economie all contained public bath-houses at which this operation could be effectively carried out. As a rule, such bath-houses were associated with large barracks. The Russian bath arrangements were as follows: On entering the bath-house each man received a series of tallies which he attached to his clothes in the undressing room. Clothes suitable for treatment by steam were passed through a hatch

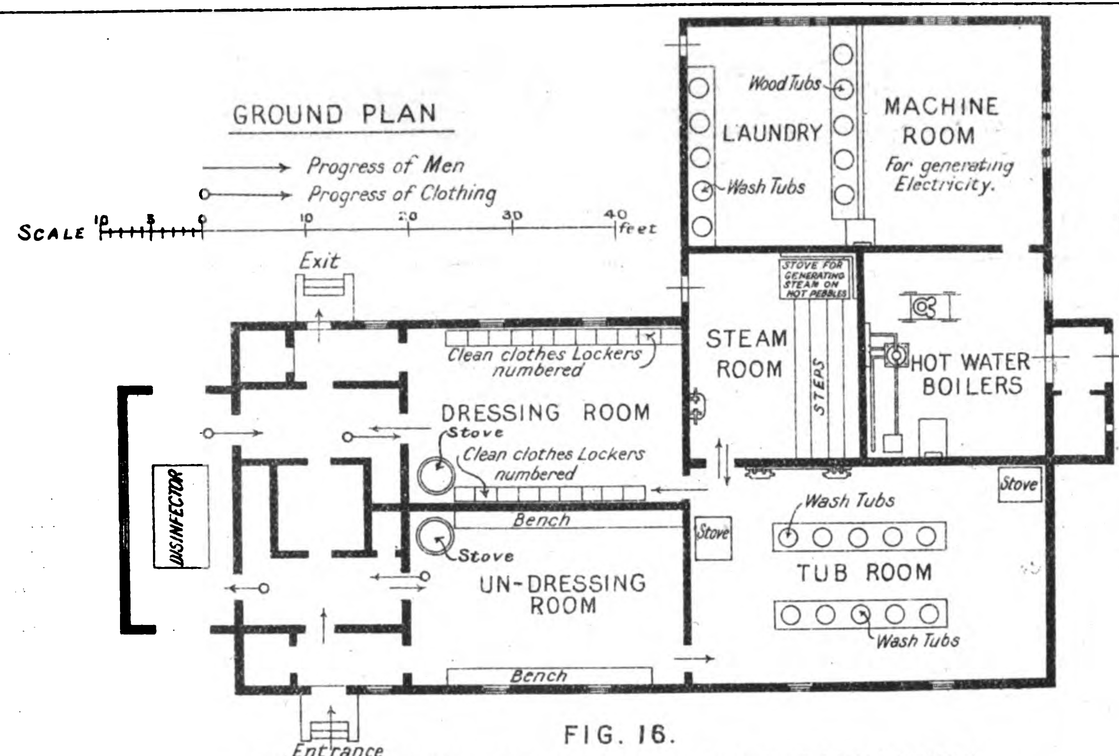

FIG. 16.

PLAN OF MILITARY BATH HOUSE, BAKHARITZA.

RUSSIAN BATH TAKEN OVER AND ADAPTED FOR DISINFESTATION.

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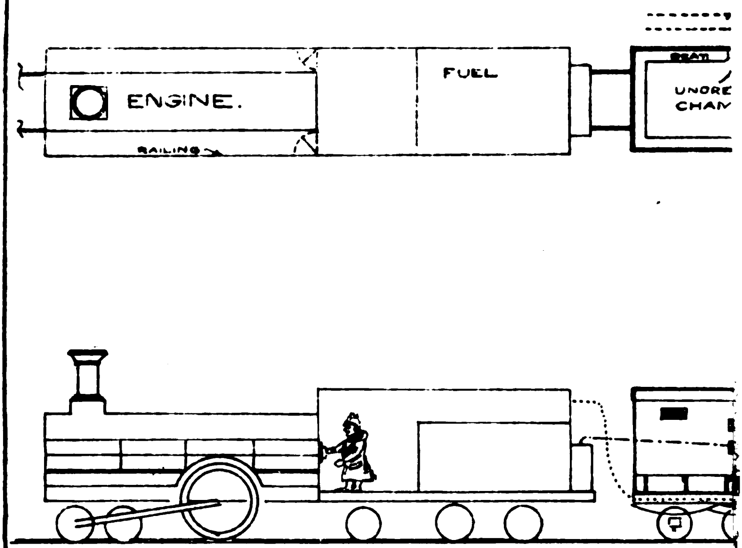
Malby & Sons, Lith.



REFERENCE.

PROGRESS OF MEN SHOWN BY ------
" " CLOTHING " " ———
STEAM PIPES SHOWN BY ....
COLD WATER SUPPLY SHOWN BY —·—·—

10 5 0 10 20 30

SCALE OF FEET.

SANI

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to the disinfecting room, where the steam apparatus was placed, boots and articles perishable by steam being left in a pigeon-hole. From the undressing room the bather passed to the waiting room where he was expected to cleanse his head, hands and feet in basins filled with hot water supplied by attendants. He then entered the vapour room where the actual bath was received. Here were wide platforms in tiers on which he reclined. Steam was generated by an attendant whose duty it was to throw a bucketful of water over a heap of large round stones heated to a high degree of temperature by wood fires. This operation was the essential feature of a Russian bath. The bather reclined at ease on one of the platforms, passing thereafter to the dressing room, where on returning the appropriate tally he received his clothes which had been disinfected whilst he had been bathing. His boots in the meantime had been transferred from the undressing room to the dressing room. He then left the building by an exit door.

The arrangements worked smoothly, close attention being given to the details of organization, which corresponded very closely to those commonly adopted on the Western front. The Force was fortunate in finding on arrival at Archangel that admirable combined bathing and disinfecting facilities could be made use of by the troops at comparatively short notice. In some cases the establishments were taken over from the Russians, since it was necessary in bathing and disinfecting comparatively large numbers of troops to control the arrangements by means of trained British personnel. In other cases Russian bath-houses were adapted as delousing stations by the British and fitted with disinfectors.

The needs of the railway force and its particular line of communication were met to a considerable extent by a mobile bathing and disinfecting train which was planned by the senior sanitary officer and the officer commanding No. 125 Sanitary Section (Fig. 17). The adaptation of the rolling stock to this purpose was entirely undertaken by the personnel of the sanitary section.

The train consisted of (*a*) a disabled locomotive capable of producing steam but incapable of running on it ; (*b*) one third-class sleeping car and (*c*) one fourth-class sleeping car, and (*d*) two 20-ft. freight wagons. The third-class car was gutted and divided into two unequal portions, one-third of the length being made into an undressing room and the remaining two-thirds into a bathing chamber. Doors at either side gave

access to the undressing room. The interior was provided with benches placed round the walls of the carriage and was heated by a stove. The bathing chamber also was benched and contained eighteen wooden tubs. Two 100-gal. iron drums were installed which received their supply of water through a hand-pump tank worked in the chamber from a large cold water supply tank on the engine. The water in one of the tanks was heated by steam supplied through a pipe from the engine. Eighteen men were able to receive hot baths at the same time. Whilst these were bathing the water was heating for the next batch thirty minutes later. A small portion of the end of the waggon was converted into a two-seated latrine of the pail-closet type.

A covered way connected the bathing chamber with a 20-ft. wagon which had been converted to form a dressing room. Suitably warmed and provided with benches, it was similar to the undressing room except that pigeon-holes under the benches were added for the reception of boots and other articles removed from the undressing room and placed there to await the arrival of the bathers from the bathing chamber.

Another covered way led from the dressing room into the rear of the fourth-class sleeping car, which had been gutted also. The first portion of this car served as the exit for the bathers. The next portion was constructed to form a combined kitchen and mess-room for the train staff—four in number—and contained a stove, which also acted as a cooker, bench and a table. Adjoining thereto and occupying a central position in the car were the staff sleeping quarters with four bunks and a stove. The last portion of the car was converted into a disinfecting chamber.

A sleeping car was selected deliberately for the purpose of accommodating a disinfecting room, since great care had been exercised by the Russians in the building of such coaches, particularly with a view to making them air-tight and heat retaining. There was no need, therefore, to arrange for double lining the interior as this had already been most efficiently undertaken.

After construction the room had a cubic capacity of about 700 to 800 cub. ft. Steam was led to the room from the boiler of the locomotive in pipes which were laid along the floors of the carriages and wagon between the disinfecting chamber and the engine. The pipes were exposed to the outside air only between carriages, and between the wagon and engine, and were adequately protected from the low temperature by suitable covering.

Within the chamber the pipes were arranged in wide coils on the sides, the floor and ceiling, to ensure a uniform temperature, so that when steam was introduced from a jet in the ceiling preliminary condensation was prevented. The entrance and exit doors were securely closed by felt jointing. A temperature of 102° C. was maintained in spite of the fact that the atmospheric temperature registered 30° to 40° of frost. The kits of eighteen men were readily dealt with and thoroughly disinfected in the time allotted. In actual practice the time of disinfection was about fifteen minutes, since the kits had to be collected in a sleigh or small cart from the undressing room, conveyed a distance of 33 yards to the disinfecting chamber, and then after treatment returned to the dressing room.

The last truck was a spare wagon in which the different appliances used by the staff in keeping the train in working order were stored.

The train moved from point to point on the railway line of communication and forward areas as required. Its headquarters were at Bakharitza at the base, whence it could be requisitioned.

A central disinfecting station was established in Archangel at the headquarters of No. 125 Sanitary Section, in view of the fact that there was no adequate disinfecting station controlled by the Russian local authority as part of the town's health services. Furthermore, about the end of February 1919 the town was threatened with an epidemic of typhus fever, and it was felt that, in the interests both of the civil inhabitants and the occupying troops, definite provisions of this nature should be made. A large Manlove and Alliott's apparatus was installed in a specially erected building, the arrangements being directly under the control of the officer commanding No. 125 Sanitary Section. Civil as well as military articles were accepted for disinfection at this station and a great amount of useful and necessary work, including bathing, was done.

At each of the two base hospitals, No. 85 General Hospital and No. 53 Stationary hospital, and also at the headquarters of No. 82 Casualty Clearing Station at Bakharitza, special disinfecting arrangements were made in a reception section. By these means the importation into the hospital wards of disease, lice, or scabies was obviated, except in the case of urgent admissions when access to the wards was direct. The reception section was planned to provide an inspection room in which medical officers first saw the cases, a dressing room

where the patient discarded his service dress and received the hospital clothing, a bath-room, and a disinfector in which all service dress and other clothing were sterilized before being placed in the adjacent pack store.

The Russian pit disinfector was not used in this part of Russia since the nature of the soil too frequently precluded deep digging.

Mackenzie sprays were constantly used for the disinfection of premises, leather goods and other articles which would have been destroyed by steam. Cresol solution was the chemical agent invariably used. No other disinfecting agents were required, except formalin, and little of this was available. The Russian depended to a great extent upon sulphur. When necessity arose this agent could be procured locally, although at high cost. Sulphur was used in an attempt to clear wooden barracks of bugs. The effect, however, was merely palliative and the infestations recurred later as markedly as before. No absolute eradication from a wooden building seemed possible short of destroying both the bugs and the building by fire.

Disinfestation on Demobilization.

At the end of December 1918 the best means of ensuring that the troops returning to the United Kingdom on demobilization should be free from vermin was under consideration. It was thought that the disinfestation of clothing and the issue of clean underclothing would best be effected before the men embarked as there would not be any time for this to be done in dispersal stations in England. In view of the fact that facilities at the disposal of formations in the field for the disinfection of uniforms would not be adequate to deal with the large number of men who would be released daily for dispersal, and also because of the liability of men to pick up vermin again in railway carriages or billets on the way to their ports of embarkation, it seemed that the only certain method of ensuring that men would be free from vermin before sailing for England was to make arrangements at the embarkation camps for the necessary bathing, issue of clean underclothes, and disinfestation of their uniforms. It was accordingly decided to prepare disinfestation stations at Boulogne (Fig. 18), Calais, Rouen, Havre, Dunkirk, and Dieppe, in special dispersal camps.* At every disinfestation station the dispersal camp

* It is of interest to compare these with the quarantine stations established by the Japanese for disinfecting the troops returning from the Manchurian campaign in 1905. See Medical and Sanitary Reports of the Russo-Japanese War, Report 36, p. 463 *et seq.*, published by H.M. Stationery Office, 1908.

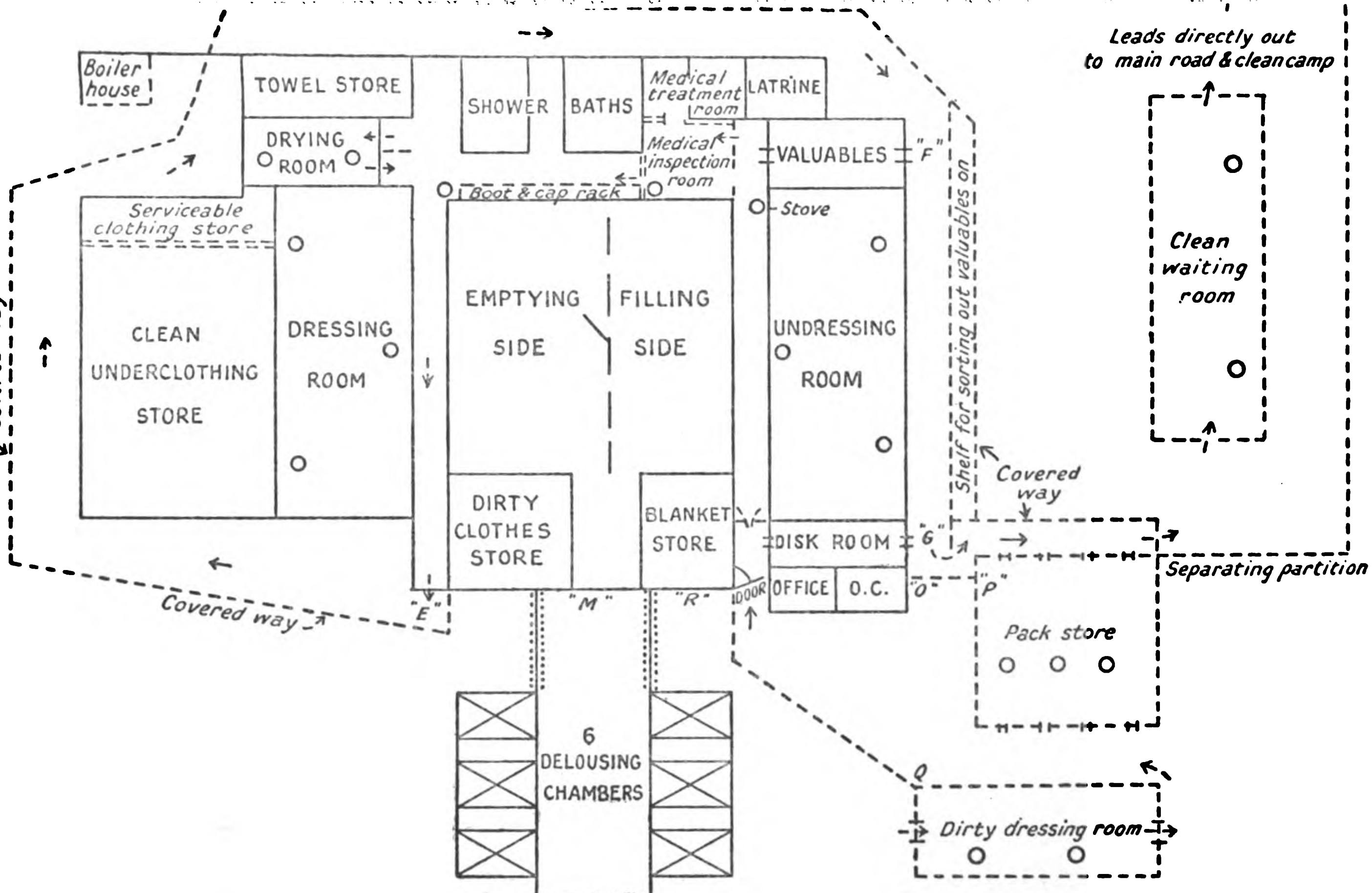


Fig. 18.—Diagram of central delousing and bathing station, St. Martin's Camp, Boulogne Base, as actually functioning in February 1919.

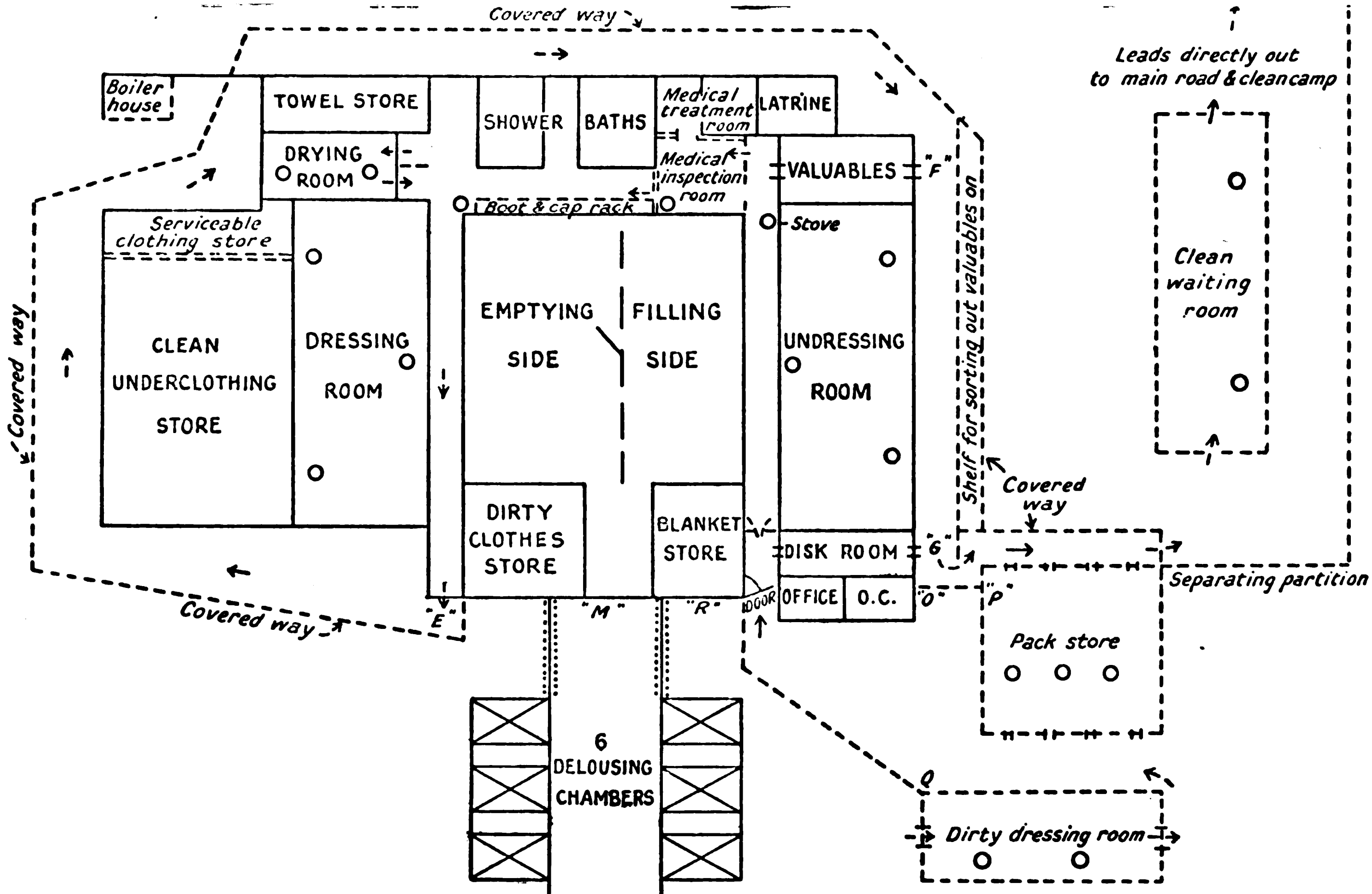
After medical inspection the men deposited their caps, leggings and boots in special racks and took their places under the shower-baths. After bathing they proceeded to the towel issuing store, and having received a clean towel entered the drying room. All men who had been shaved were given an ointment of 25 per cent. ammoniated mercury to apply to the affected parts. The men then took their caps and boots and entered the dressing room. On reaching the dressing room each man occupied the seat bearing his number and drew from the nearest window of the clothing store a clean suit of underclothing, consisting of shirt, vest, pants, and socks. He then waited until the attendant brought him the coat-hook bearing his garments which had been passed through the disinfestation chamber. On completing their toilet the men passed out of the building, leaving their coat-hooks above their seats so that they might be collected by the attendant, and handed in their towels as they passed the dirty towel store.

On leaving the building the men, still in possession of their equipment discs and their clothing discs, proceeded round the building under the covered way to the issuing hatch of the valuable room, where on showing their equipment discs the "valuables" bags with attached discs of the same number were returned to them.

The men then placed the valuables in their pockets and handed in their clothing discs and "valuables" bags at the receiving window of the disc room. They then received their rifles and equipment in exchange for the equipment discs, and were marched off to the despatch division or clean camp where a second medical inspection was made. Later this second medical inspection was omitted as practically no men were found to be verminous.

In the first scheme no provision was made at first for the disinfestation of the spare underclothing in the packs of the men passing through, as it was found very difficult to treat such clothing in the allotted time. Orders were therefore issued to ensure that no such underclothing remained in the possession of the men. Later, when arrangements were working smoothly, articles of clothing carried in the packs were replaced by clean ones and by this means the possibility of re-infestation was removed.

The arrangements at all bases were on these lines, the size of the camps varying according to the number of men passing through that particular base. At the commencement of demobilization a few complaints about the arrival of lousy



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General Conclusions.

It is of interest to consider what lessons have been learned by the experience of measures for preventing infestation by lice during the war, and as a general guide for any subsequent campaign the following points are worthy of consideration.

1. It is probable that in the war 50 per cent. of the admissions to hospital from troops in the field armies were attributable to lack of personal cleanliness and to vermin.

2. The establishment of laundries and provision of facilities for bathing and for disinfestation are essential in the areas occupied by troops. In front of railheads the laundries, bathing arrangements and disinfestors should be mobile.

3. In the field armies a single chamber steam disinfestor (also disinfector if required) on a light motor lorry would be most useful. Such a disinfestor could be used in brigade or even in regimental rest areas ; it could also be employed with a cavalry division. A number of these disinfestors could be massed together at divisional bathing installations.

4. A douche system of bathing, such as the Le Blanc, seems to be most suitable for use with divisions or brigades. It is essentially portable and reduces the amount of water used, a matter of great practical importance in the field. It can even be employed in the trenches.

5. For isolated units and for hill warfare or in other areas where there are no roads suitable for motor transport the sack disinfestor would be most suitable.

6. In casualty clearing stations and medical units which are likely to be moved at frequent intervals the single chamber disinfestor (and disinfector) is to be recommended.

7. For fixed camps on the L. of C. and for general disinfestation on demobilization, hot-air disinfestors as are most suitable.

8. For general hospitals at bases and on the L. of C. fixed types of steam disinfectors, such as the Equifex, Washington, Lyon, Thresh, Barford and Perkins, are to be preferred.

The investigation was carried out at Cambridge and the material used was derived from scabies patients at No. 1 Eastern General Hospital. The experimental and microscopical parts of the work were carried out in the Quick Laboratory, Cambridge, under the direction of Professor G. H. Nuttall. The experiments on the infectivity of clothing were made at the Cambridge Research Hospital.

The scabies cases arrived at No. 1 Eastern General Hospital from the home forces and also from overseas. The hospital also received cases which had been partly treated and numerous cases of so-called impetigo and boils which were scabitic in origin. On the whole, therefore, the scabies cases studied were typical of the disease as it manifested itself in the army. A full report of the investigation was published in July 1919 in the *Journal of the Royal Army Medical Corps*.

The life-cycle of *S. scabiei*, var. *hominis*, as described by Captain Munro, occupies a period of nine to fifteen days.

Egg stage	2½ to 3½ days.
Larval stage	1½ to 3 „
Nymphal „	1½ to 2½ „
Second nymphal stage	2 to 4 „

The adult female lives certainly for at least three weeks; the male probably lives for a similar period. The adult and those in the second nymphal stage make horizontal linear burrows in the upper epidermis. The larvæ bore more deeply either in the floor of the egg burrows or away from the burrows in the immediate neighbourhood of the hair-follicles, and the irritation caused by their burrows gives rise to vesicles containing the serous fluid. The habits of the first nymph are not known and it has not been possible to study them. Copulation probably takes place in the burrows made by the second nymphs, males having been observed in these burrows or in small branch burrows off them.

Egg-laying is dependent on temperature, and the hatching of the egg is dependent on temperature and humidity. It can be interrupted or delayed up to at least six days without destruction of the hatching power but development is proportionately slower.

Effects of Heat and Moisture on Acari and Ova.

A number of experiments on the effects of heat and moisture on acari and ova were carried out. The acari and ova were placed in a Nuttall's thermostat and observed through the microscope, as no means of detecting death, or distinguishing

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In vitro the results obtained were that moderate humidity is as important for the well-being of the mite as moderate temperature. When the humidity was high (70 per cent.) the mites survived a temperature of 55° C. for more than half an hour. When the humidity was low (40 per cent.) they survived the same temperature for from ten to fifteen minutes only. With a high humidity (70 per cent.) they survived a temperature of 40° C. for four hours, but with a low humidity they were shrivelled in twenty minutes. Ova withstood drying better than the acari, resisting 55° C. dry (40 per cent. humidity) for twenty to thirty minutes and 40° C. for four hours. With 70 per cent. humidity they survived for half an hour at 55° C. and for twelve hours at 40° C.

Similar results were obtained with acari and ova placed and covered up in cotton, except that at moderate temperatures, 30° to 40° C., they resisted dry conditions better. Acari resisted for thirty to forty minutes and in one case for an hour before becoming shrivelled. Ova withstood the dry conditions for twenty-four to thirty-six hours.

In these experiments death was determined by the shrivelling of the integument. In the first instance the attempt was made to revive the mites, but all failed, and the shrivelling of the skin was considered adequate proof of death. Movement was looked for, but no signs of it were ever manifested by the shrivelled or half-shrivelled mites. Ova collapsed with drying, and although, in two instances, their turgidity was partly restored by moistening them, the contents of the egg became opaque and no development was observed. The collapse and opacity of the ova were accordingly accepted as proof of destruction and death.

Experiments on Infectivity.

Captain Munro carried out a series of experiments to test the infectivity of blankets, clothing, and other probable fomites. In the first instance a number of preliminary experiments were made on the transference of individual mites from the

Professor Darier's opinion that the disease is largely venereal in origin is to a certain degree true in so far as the term "venereal in origin" implies intimate and prolonged contact. On the other hand, close and prolonged contact, as when two men or a mother and children sleep together, is equally favourable to the spread of the disease, and equally important. In this connection it is interesting to note that at Cherry Hinton Military Hospital the percentage of cases of gonorrhœa combined with scabies, and syphilis combined with scabies, was only 3·5. So low a percentage, if an average one, seems to indicate that Professor Darier's term "venereal" must not be accepted too literally.

Infection from Domestic Animals.—Several varieties of *S. scabiei* which normally occur in domestic animals may give rise to a form of scabies in man.

The ætiology of scabies may from the above facts be summarized as follows: It is due to the presence in the skin of the mite *S. scabiei* var. *hominis*, which is conveyed from person to person by body contact, by blankets and clothing. The clothing of persons suffering from scabies may remain infective for at least eleven days. A form of scabies may also be contracted from certain domestic animals suffering from mange, of which the horse is probably the most important.

Disinfestation.

Acari and ova placed in small glass tubes, which were wrapped in clothing and then placed in a steam hut at No. 1 Eastern General Hospital, Cambridge, were destroyed by twenty-five minutes' exposure to the working temperature of the hut (65° C.). This result, together with experiments on the effects of heat and moisture on acari and ova, already described, show that the disinfection of scabies fomites can be carried out by the dry and moist heat methods recommended for louse destruction in the preceding chapter.

The Control of Scabies.

The control of scabies depends on accurate and early diagnosis of the disease and weekly routine inspection of troops, upon careful mechanical and acaricidal treatment, and upon adequate disinfection of clothing and bedding of infected persons. Personal cleanliness goes far to prevent the spread of the disease.

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The chief points in the diagnosis of scabies are set forth in a memorandum on scabies issued by the War Office in 1918 as follows :—

" Signs of scratching and irregularly scattered reddish papules on the chest, abdomen, and upper and lower extremities.

" The presence of the burrows of the acarus on and between the fingers, on the front of the ulnar margin of the wrists, on the elbows and the front of the axillæ, on the penis, scrotum and buttocks, and around the ankles.

" The presence of small vesicles on the sites defined above."

In carrying out weekly routine inspections of men for scabies or of scabies patients under treatment, the following rules proved useful :—

The men were stripped so that the abdomen, pubic region, thighs and buttocks could be examined; the inspection was conducted in a well-lighted warm room or hut. Open-air inspections for scabies were almost useless.

The first step was to pick out and segregate all men showing the lesions and eruptions already referred to as diagnostic. Those men whose skins were free from such appearances were regarded as clean and dismissed. Having segregated the cases these were now examined more closely, and here the lens was used. Brief notes were made on each case, showing the localization of the lesions, and the resultant diagnosis.

In actual practice it was found that the diagnosis of scabies depended almost wholly on three factors: the occurrence of (1) burrows, (2) acari on the wrists or on the penis, and (3) of ecthymatous impetigo on the buttocks. In the great majority of cases at No. 1 Eastern General Hospital these three appearances constituted the diagnosis of scabies.

Scabies being due to the presence in the skin of the itch-mite, cure can only be effected by removing or destroying the acarus.

This may be achieved in two ways, either by removing and killing the acarus mechanically or by destroying it in its burrow by means of an acaricide. In actual practice a combination of the two methods is usually adopted, consisting of a mechanical preparatory treatment followed by treatment with an acaricide. Full instructions as to treatment were given in the War Office pamphlet on Scabies, issued in 1918.*

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were frequently infected, or by men returning from leave. At one time drafts arriving from England were found to be infected, chiefly at a time when efficient medical inspection was difficult owing to the necessity of hurrying troops to the theatres of war. As far as possible every effort was made to eliminate all infected men from drafts intended to reinforce the divisions in the field.

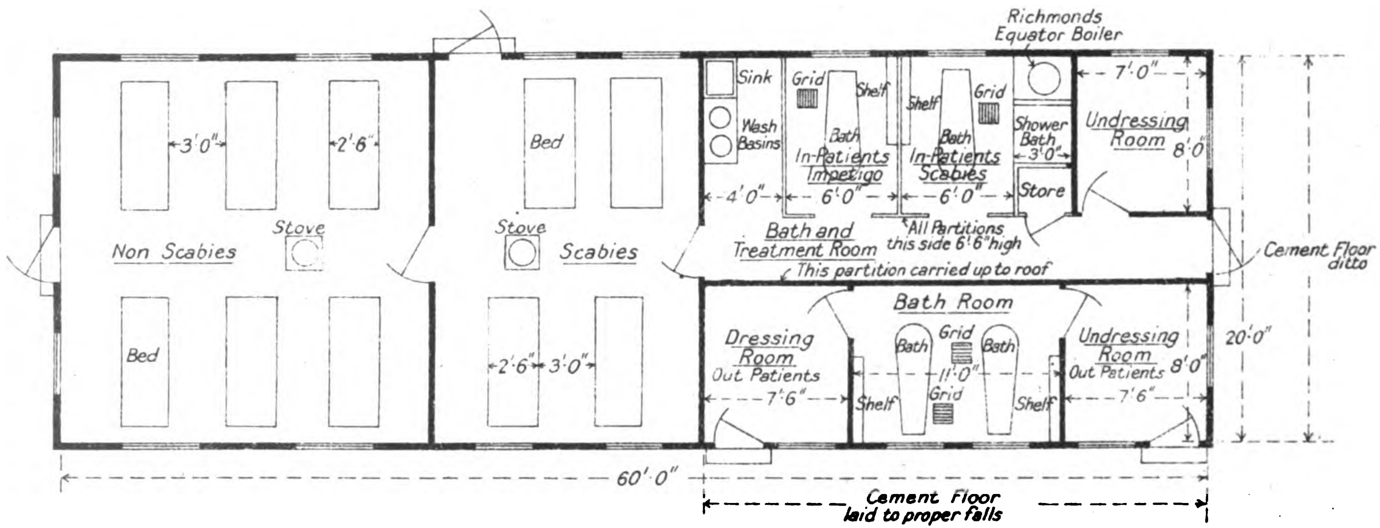
The measures of prevention adopted were practically the same in all the allied armies, differing only in detail as regards methods of treatment and disinfection. In the British army in France, the rigorous campaign of prevention, advocated by the skin specialists, consulting physicians and hygienists in 1917 and 1918, resulted in a considerable reduction of the incidence. Scabies was not evenly distributed throughout the units, divisions, corps or armies in the field, many being entirely free whilst others were heavily infected. In addition, a division which remained comparatively free in one area would become infected on moving to a fresh area. This circumstance, which might have arisen from a variety of causes, was often difficult of explanation.

Men suffering from scabies were admitted to special scabies centres which were established in corps and divisional areas. The personnel for these centres was taken from field ambulances and the work was carried out under the direction of corps or divisional headquarters as the case might be. In the back area of one army, the Fourth Army, an army scabies centre was also established to accommodate 300 patients in huts, this being intended to supplement corps and divisional centres in the forward areas of the army.

Many corps established scabies centres for treating all the cases occurring in the area, whilst in other areas, provision for the treatment of scabies was left to divisions, which formed centres conducted by a section of a field ambulance. In these instances the scabies treatment centres sometimes formed part of the divisional rest station, but were more frequently independent.

During a period of military activity it was found that there were obvious advantages from the tactical point of view in retaining the lighter cases within the division, as they were available to reinforce the fighting line if necessary, but, if no corps centres had existed, the more complicated cases and those from corps and army troops would probably have suffered from lack of facility for treatment.

Note:- The Grids are movable and may be placed in any position.



GROUND PLAN.

FIG. I.

SKETCH PLAN OF SCABIES RECEPTION STATION AND TREATMENT CENTRE.

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Malby & Sons. Lith.

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* See also Vol. II, Diseases of the War, Chapter II.

were frequently infected, or by men returning from leave. At one time drafts arriving from England were found to be infected, chiefly at a time when efficient medical inspection was difficult owing to the necessity of hurrying troops to the theatres of war. As far as possible every effort was made to eliminate all infected men from drafts intended to reinforce the divisions in the field.

The measures of prevention adopted were practically the same in all the allied armies, differing only in detail as regards methods of treatment and disinfection. In the British army in France, the rigorous campaign of prevention, advocated by the skin specialists, consulting physicians and hygienists in 1917 and 1918, resulted in a considerable reduction of the incidence. Scabies was not evenly distributed throughout the units, divisions, corps or armies in the field, many being entirely free whilst others were heavily infected. In addition, a division which remained comparatively free in one area would become infected on moving to a fresh area. This circumstance, which might have arisen from a variety of causes, was often difficult of explanation.

Men suffering from scabies were admitted to special scabies centres which were established in corps and divisional areas. The personnel for these centres was taken from field ambulances and the work was carried out under the direction of corps or divisional headquarters as the case might be. In the back area of one army, the Fourth Army, an army scabies centre was also established to accommodate 300 patients in huts, this being intended to supplement corps and divisional centres in the forward areas of the army.

Many corps established scabies centres for treating all the cases occurring in the area, whilst in other areas, provision for the treatment of scabies was left to divisions, which formed centres conducted by a section of a field ambulance. In these instances the scabies treatment centres sometimes formed part of the divisional rest station, but were more frequently independent.

During a period of military activity it was found that there were obvious advantages from the tactical point of view in retaining the lighter cases within the division, as they were available to reinforce the fighting line if necessary, but, if no corps centres had existed, the more complicated cases and those from corps and army troops would probably have suffered from lack of facility for treatment.

Special stress was laid on the necessity of regular body inspections of the men by medical officers, and also by means of circular memoranda and instruction at schools upon the special points of diagnosis of scabies in the field, since in its early detection and accurate diagnosis lay the chief means of prevention. In many divisions specially trained non-commissioned officers were stationed at baths, who reported the names of all men showing signs of skin disease. In some formations the medical officers of units were present at the divisional baths during bathing and carried out inspections of all the men when naked. This was probably the most satisfactory method of carrying out inspections.

Arrangements for the treatment of scabies were often considerably disorganized by rapid moves of formations, and treatment had to be suspended during heavy fighting, since patients fit to fight had of necessity to be retained with their unit.

In regard to the most effective method of treatment, the general opinion among medical officers who were in charge of scabies centres inclined to a daily cycle of bathing, scrubbing the skin with soap and hot water, and inunction with sulphur ointment.

On arrival at a scabies centre the patient's clothing was removed and disinfected by steam. Hospital clothing was worn until cure was effected. Frequently a further change of hospital clothing was given after the third day of treatment. Daily inspection of all cases was carried out by a medical officer.

In regard to bathing, the practice in most centres was to give one hot bath daily; at some centres, however, the patient was bathed on the first day and again on the fourth day and subsequently on discharge.

It was found necessary that baths should be of the slipper type so as to allow complete immersion of the body, and that patients should remain in the water from twenty to thirty minutes at a time, the temperature of the water being maintained by the addition of hot water from time to time, as required. Spray baths did not give satisfactory results, but vapour baths followed by hot sprays proved to be very beneficial.

With a view to opening the external orifice of the burrows, great value was placed on scrubbing the skin with a hard nail-brush, followed by vigorous towelling.

Inunction, or the use of the liquor calcis sulphuratæ, was carried out immediately after the patient was bathed. It

was the general practice to carry out inunction on the first, second and third days after admission, and a strict watch was kept for any signs of commencing dermatitis. Subsequent bathing and inunction were regulated according to the condition of the patient.

Sulphur ointment prepared with precipitated sulphur was found to have a less irritating effect than that prepared from the sublimed variety. It was also considered that sulphur irritation did not so often occur when the sulphur was in solution as when it was in suspension.

All patients were strictly segregated until they had received one complete round of treatment, including inspection, bath, inunction, and change of clothing. In uncomplicated cases of scabies nothing seemed to be gained by separating men at various stages of treatment, provided one cycle had been completed.

Although there appeared to be a general agreement regarding the methods of treatment in hospitals, opinions differed as to the length of time necessary to effect a cure. It would seem that there were two main causes of the apparent lack of agreement on this question. In the first place, it was not always easy to decide when a cure had been effected, that is, when the body had been entirely freed from the acarus and its eggs ; on the other hand, so many of the cases were complicated by concurrent skin affections, the cure of which required a much longer time than that of the scabies itself, that there was great variation in the number of days required for cure, quite apart from the question of freeing the patient from the parasite.

In the army treatment centres the usual duration of treatment was from five to seven days. For example, in the XIth Corps scabies centre, 550 cases were treated in nine weeks from 22nd January, 1918, to 25th March, 1918. The average duration of treatment was 3·5 days, and the officer commanding claimed that there was no single instance of a case returned that could be said to have been discharged uncured.

The average number of days in hospital entirely depended on whether the case was complicated, and the nature of the complication. In hospitals on the lines of communication the average duration of treatment for uncomplicated cases varied between six and fourteen days, and for complicated cases from seventeen to fifty or more days, according to the nature of the complication.

In regard to preventive measures found useful in the field, the most important of these were frequent and regular inspection of the men by the medical officers and officers commanding units, regular bathing, disinfection of effects, especially blankets, the regular change of underclothing, and inspection at the bath-houses during bathing parades. The advisability of appointing to each unit a specially-trained non-commissioned officer, whose special duty was to attend all bathing parades and examine every man whilst naked, was considered. Undoubtedly, this would be more satisfactory than merely stationing a man at each bath-house, since the trained non-commissioned officer could then check the list of bathers against the nominal roll of the unit, and thus prevent individuals on special duty, such as cooks, orderly-room clerks, and others, from missing the regular inspection, bath, and change of underclothing.

The regular disinfection of latrine seats with cresol was often resorted to and is certainly a valuable measure in prevention. It is difficult, however, to carry it out in the field, owing to the frequent lack of the necessary personnel. On the occurrence of a case of scabies in any unit, an immediate inspection of all men in the same billet, hut, or tent was considered essential, and if the case was one that had been reported in the early stages, and no other men in the quarters showed signs of the disease, it was considered sufficient to treat as contacts the four men who occupied beds, two on each side of the infected man. Where the infected man evidently had suffered for a more or less prolonged period before diagnosis was established, it was considered advisable to treat all the inmates of the same hut or billet as contacts.

A considerable aid to the suppression of scabies and allied disorders, which cause temporary wastage in the field, is the fearless recording of cases, and the publishing of tables and curves from every unit, in order that officers commanding may be fully informed and realize the condition of their unit. This procedure will also indicate the direction in which the disease is spreading.

CHAPTER XIV.

PREVENTION OF BILHARZIASIS (SCHISTOSOMIASIS).

PRIOR to the commencement of the war in 1914 medical officers of the regular army were well acquainted with bilharziasis, or to use the more scientific term, schistosomiasis, as a disease affecting soldiers, but measures for its prevention were uncertain and the methods of its transmission to the human body still under investigation. Service in Egypt and in South Africa had given them opportunities of observing the disease among the native populations in these countries, while officers serving in the United Kingdom had seen its results, severe anæmia and debility, among the pensioners who came up periodically for re-examination. There was, however, little definite knowledge on the subject.

Simpson, in his "Medical History of the South African Campaign," stated that the actual number of cases of bilharziasis admitted to military hospitals during the South African War was 187. This number must not be considered as representing the total number of cases, because, as he goes on to state, there were many slight cases so trivial in character that they passed unnoticed.

Cottell, in an article in the *Journal of the Royal Army Medical Corps* in 1912, brings out the fact that 625 men were infected with schistosomiasis in South Africa, and that 359 of these were still on the pensions list in 1911, exclusive of those permanently pensioned. These numbers represent in actual pensions £10,800 per annum.

The total number of admissions from the army at home and abroad during 1913 was six.

As regards the prevention of the disease, Simpson pointed out that nothing bearing on the mode of infection was observed during the South African campaign and that it seemed desirable that some definite rules should be laid down; while Lord Kitchener, in his annual report on Egypt for 1913, expressed the view that "it is high time that serious steps should be taken to prevent the continuity of infection that has been going on so long in this country."

Research work on the life-history of the parasite, however, had not been fully carried out. The ætiology of the disease and its mode of infection were still unsolved problems. Little was known about the prevention of schistosomiasis, and all drugs that had been tried had failed to effect a cure. It was

not surprising, therefore, that medical officers viewed this disease as a likely cause of serious inefficiency.

Although Bilharz in 1851 first discovered paired trematode worms in the portal system of an Egyptian fellaheen, numerous later attempts by various observers failed to unravel the life-history of the parasite. Naturally the intermediate molluscan host was looked for, and when Looss failed to find the cercariæ of schistosomum in the snails he dissected from species collected in the fresh-water canals around Cairo, he evolved the hypothesis that man acted simultaneously as the intermediary as well as the definite host of the parasite. He also denied the existence of two species, the *Schistosomum haematobium* which produced terminally spined ova found in the urine, and the *Schistosomum mansoni* which produced ova with lateral spines, only found in the fæces.

During 1914 Dr. R. T. Leiper reported to the War Office several facts that threw discredit upon the Looss hypothesis. The Army Council, in view of the fact that there would be a considerable concentration of troops in Egypt, authorized Dr. Leiper with the temporary rank of Lieutenant-Colonel to proceed to Egypt to investigate schistosomiasis and to advise as to the preventive measures required. Associated with him were Dr. R. P. Cockin and Dr. J. G. Thomson. The Committee of the London School of Tropical Medicine furnished the requisite scientific apparatus, and the Medical Research Committee gave a grant for the necessary field and other expenses incidental to the research. The mission arrived in Egypt on 8th February, 1915, and returned to England on 15th July, 1915. The vacant parasitology laboratories in the School of Medicine in Cairo were set apart for the use of the mission, and facilities for keeping experimental animals were provided at the Bacteriological Institute.

Investigations were begun at the small agricultural village of El Marg, situated some nine miles north of Cairo on a small canal which coursed from the main Ismailia Canal and supplied the village and numerous fields with water. The population of the village numbered about 5,000, the majority of whom were agricultural labourers. A start was made by examining the urine of fifty-four boys, and in forty-nine cases ova were discovered. It was natural that young people should be selected, as all observers of the disease in the countries where it is endemic have clearly shown that the majority of cases found suffering from schistosomiasis acquire the infection in their youth. The affection in the majority of cases is slight, and a spontaneous cure often takes place.

The conditions at El Marg were ideal for the commencement of the investigation, and it was decided to make a complete census of all fresh-water molluscs in the neighbourhood. The supply of water in the main canal was controlled by the Government of Egypt on the system of a six days' flow followed by fifteen days' stoppage, the rotation commencing early in April. During the period when the water was cut off the Marg canal became dry except where the unevenness of the ground left small puddles. This fortunate circumstance enabled the mission to make a comprehensive survey, and the following species of molluscs were retrieved: *Melania tuberculata, Vivipara unicolor, Cleopatra bulimoides, C. cyclostomoides, Bullinus dybowski, B. alexandrinus, B. contortus, B. innesi, Pyrgophysa forskali, Lanistes bolteni, Planorbis boissyi, P. mareoticus, Limnaea Caillaudi, Bythinia (Gabbia) sennaarica, Valvata nilotica,* and some bivalves. The commonest species were *Planorbis boissyi, Bullinus,* and *Cleopatra.*

These molluscs were examined by direct inspection and by dissection, and the following table shows the cercarial forms identified by Leiper and previous observers :—

Molluscan Host.	Name of Larva.	Sonsino, 1892.	Looss, 1896.	Leiper, 1915.
Cleopatra ..	(1) *Gastrodiscus aegyptiacus*	—	+	+
	(2) *Cercaria distomatosa* ..	+	+	+
	(3) *Cercaria vivax* ..	+	+	+
	(4) *Cercaria exigua* ..	—	+	+
	(5) *Cercaria microcotyla* ..	+	—	+
	(6) *Cercaria capsularia* ..	+	+	—
	(7) *Cercaria cristata* ..	+	—	+
Limnæa ..	(8) *Cercaria obscura* ..	+	—	+
Bullinus ..	(9) *Cercaria pigmentata* ..	+	+	+
	(10) *Cercaria agilis* ..	+	—	+
	(11) *Cercaria fissicauda* ..	+	—	+
B. (Pyrgophysa)	(12) *Cercaria pigmentata* ..	+	+	+
Melania	(13) *Cercaria pleurolophocerca*	+	+	+
	(14) *Cercaria cellulosa* ..	—	+	+
	(15) *Cercaria monostomi verrucosum* ..	—	+	+
	(16) *Cercaria microcristata*	+	—	+
	(17) *Cercaria microcotyla* ..	+	—	+
Vivipara ..	(18) *Cercaria pusilla* ..	—	+	+
Lanistes.. ..	(19) *Cercaria sp.* (?) ..	—	(?)	+

Leiper states that the essential features which differentiate the schistosomum group of cercariæ are the absence of a pharynx, the presence of a forked or bifid tail, the presence of anterior

and ventral suckers, the absence of eye-spots, and the presence of two or more sets of glands, situated posteriorly, one on either side of the mouth.

He found that molluscs obtained at spots daily frequented by natives, such as the praying-ground, in front of cafés (Fig. 1), and the bends in the canal specially used for washing, were highly infected with cercariæ; and that the following molluscs, *Planorbis boissyi*, *Bullinus sp.* (?), *Pyrgophysa forskali*, and *Limnaea truncatula* had a definite attraction for the miracidia, and that the attraction was stronger in the young specimens.

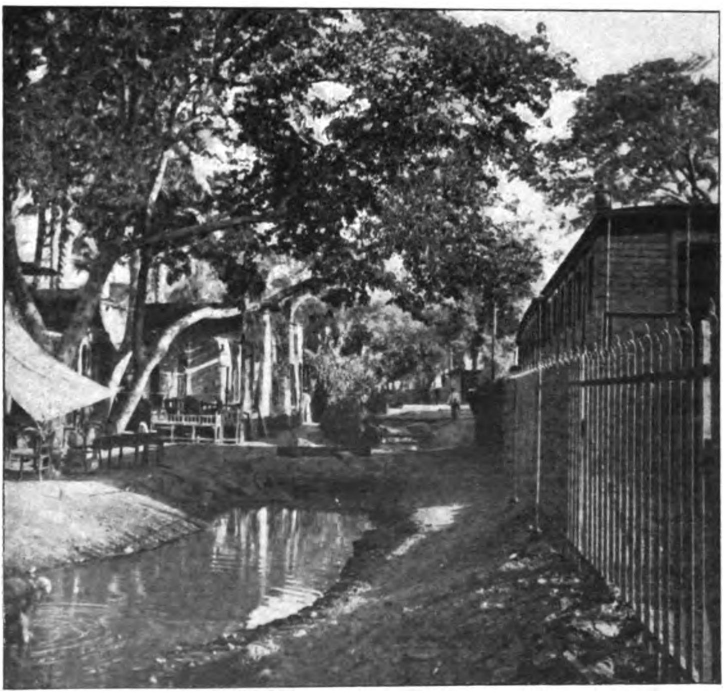

Fig. 1.—The canal skirting the village between the railway station and the cafes, El Marg.

It was noteworthy, too, that the same species of mollusc was quite common in the agricultural drains away from footpaths, but they were not infected.

The schistosomum cercariæ having been obtained from definite molluscs, attempts were next made to infect animals experimentally. These experiments were successful and a full account of them has already been published in Leiper's original

articles. It is sufficient to quote here that "in addition to tame white rats and variegated mice (brought from London), the Egyptian desert rat, obtained from the neighbourhood of the Pyramids, was found to be susceptible to experimental infection, while guinea-pigs were peculiarly so. Mangaby monkeys died of acute schistosomiasis within two months of infection. At the conclusion of its field work the mission brought back from Egypt four mice, twenty-six white rats, sixteen desert rats, two guinea-pigs, and four mangaby monkeys, which had been submitted to infection shortly before departure. When examined shortly after their arrival in England all these animals had enormous numbers of bilharzia worms in the portal system."

Experiments were also made to elucidate the exact mode of entry of the schistosomum cercariæ into the human body. These experiments proved conclusively that the infecting cercariæ entered the body through the buccal mucous membrane or through the skin ; and that, while cases infected through the mouth showed earlier and more intensive symptoms, the great majority of cases were infected through the skin, an important finding in considering preventive measures for troops in the field.

Previous writers on this disease had estimated the incubation period as follows : Sonsino as from two to three years, Sandwith as from three to six months, Beveridge as from three to seven months, while Stock asserted that in the cases observed by Abercrombie in South Africa the shortest period was one month and the longest two months. Stock's estimate agreed with the incubation period observed when the disease was produced experimentally in monkeys.

The researches, then, of the Leiper mission in Egypt elucidated the full life-history of the parasite, details of which were circulated to the Mediterranean Expeditionary Force in the following memorandum :—*

"BILHARZIASIS."

Life-history of the Parasite.

Bilharziasis is exceedingly common in Egypt. Investigations made in different districts show that not uncommonly 30 to 40 per cent. of the population are affected, and in some districts as many as 60 to 9C per cent.

In the Canal area, however, the disease appears accerding to present information to be less prevalent than in some other parts.

Recent researches have established for the first time the main facts of the life-history of the parasites causing Egyptian bilharziasis.

After escaping from the body by the urinary passages or rectum, the egg, if it reaches water, is hatched into a free swimming ciliated larva (miracidium)

* Circular Memorandum No. 9.

which dies in about twenty-four hours unless it enters a suitable host. The intermediate hosts, into the bodies of which the larvæ enter, are fresh-water molluscs (water-snails). There each larva undergoes a further development into a sporocyst, which in turn gives off many daughter sporocysts, and these finally produce innumerable cercariæ. These cercariæ are discharged from the molluscs and swim free in the water. The cercariæ are about 1½ mm. in length, and though they can be seen by the naked eye in clear water in a test-tube they cannot be detected readily in natural water.

The commonest of Egyptian molluscs which harbour bilharzia belong to different species of *Bullinus* and *Planorbis*.

The *Bullinus* is common in the Sweet Water Canal and its branches, and the *Planorbis* in the marshes and ditches around Ismailia. They are easily recognized as snail-like animals when found on the surface of the water, but when attached to vegetables or at the bottom they may be overlooked.

Their presence in water in Egypt must always be looked upon as indicating a potentially dangerous water as regards bilharziasis. Where there is a flow of water their local absence must not be taken as an indication of safety.

The cercariæ after escape from the molluscs are free swimming organisms, and it has been demonstrated experimentally that they can gain entrance to the body, both through the skin and by piercing the mucous membrane if swallowed with the water. They can survive when free in the water for thirty-six hours; none have been found alive after forty-eight hours, but an infected mollusc will continue to discharge cercariæ for a long time, certainly more than three weeks.

They can survive on a damp surface from which visible water has disappeared, but are immediately killed if the drying process proceeds to the extent of desiccation.

In the body the cercariæ are carried by the blood to the liver and get into the system, in the branches of which they develop into the full-grown worms, male and female; the process from entry to full maturity of the paired, egg-producing adults taking about two months.

Prevention.—From the life-history of the parasite, as briefly sketched above, the following conclusions bearing on the prevention of the disease may be deduced :—

(1) All permanent collections of water, such as the Nile, canals, marshes, and birkets, are potentially dangerous, depending upon the presence of the essential intermediary hosts.

The molluscs have not yet been found in wells, but their absence can only be definitely determined by examination of each well.

(2) Bathing, wading, washing in or drinking, in fact personal contact of any kind with infected water is risky.

(3) Free swimming cercariæ readily pass through stocking material, and through the finest silk mesh. Therefore, clothes, unless waterproof, are no adequate protection against them when the wearer is wading in infected water, as, for instance, in snipe shooting.

(4) Infected troops cannot reinfect themselves or spread the disease directly to others. They could only convey the disease by their excreta reaching water in which a local mollusc could efficiently act as carrier.

(5) Infection actually takes place both by the mouth and through the skin.

(6) Storage of raw water for forty-eight hours will ensure the death of all cercariæ, but on drawing the water for storage it is essential that no infected molluscs are admitted. Screening with gauze having sixteen meshes to the linear inch will ensure this.

(7) The cercariæ are killed instantly by exposure to a temperature of 50° C.

(8) Fresh chlorinated lime 1 in 50,000 kills them in three minutes. In a solution of 1 in 300,000 (1 in 100,000 of available chlorine) they are alive and active after one and a half hours.

Therefore the amount of chlorinated lime ordinarily used for killing bacteria in water is not sufficient to kill bilharzia cercariæ.

(9) Sodium bisulphate, 1 in 1,000, kills them almost immediately. One of the 2-grm. sodium bisulphate tablets used for purifying water dissolved in a water-bottle full of water represents a strength of about 1 in 600, and will therefore render the water safe.

(10) Efficient filtration renders water safe as regards bilharzia infection. The filtered water supplied to the troops of the Mediterranean Expeditionary Force may be regarded as quite safe."

D.M.S. General Headquarters,
M.E.F.,
1st February, 1916.

A concise summary of the information contained in this memorandum was published in 1916 by the War Office in "Memoranda on some Medical Diseases in the Mediterranean War Areas," and a copy was issued to all medical officers in eastern stations.

Other important points were discovered by the mission as bearing on the prevention of the disease. As it was proved impossible to keep the cercariæ alive for more than thirty-six or forty-eight hours, it followed that, if unfiltered water was stored for two days, the danger so far as schistosomiasis was concerned was slight. Again, the method of rotation of the water supply to the canals was of assistance as a preventive measure, because owing to periodical stoppages the courses became dry and the *Planorbis* and *Bullinus* consequently died off. It was found by experiment that some of the chemicals used as manures, especially ammonium sulphate, were useful in killing any molluscs that might have escaped destruction by desiccation. The regular clearing of canals and water-cuts and the substitution for them of closed drains were also recommended as being invaluable methods of preventing the molluscs breeding and excreting infected cercariæ.

In the spring of 1916 experiments were made to determine the degree of protection afforded by a modified Jewell system of filtration. The system consisted of clearing the water in a settling tank prior to filtration through a metre of sand. The water was retained in the settling tank for about eight hours. It was found that at the end of that period the cercariæ were swimming freely in the settling tank and had not been entangled in the alum precipitate. The cercariæ were also found to be able to penetrate 30 in. of sand.

From these experiments it was evident that the important fact when attempting to free water by filtration from this infection was the time taken by the water to pass through the filter. The longer the water took to pass the greater chance there was of its being freed from cercariæ. Experiments with chemicals proved that sodium bisulphate tablets which

gave a dilution of 1 in 567 in a quart bottle were sufficient to kill the cercariæ, and could be used with safety for sterilizing water in countries where schistosomiasis was endemic.

With regard to the sterilization of water by the bleaching powder method, it was found necessary to use 2 parts of available chlorine per 1,000,000, and afterwards to dechlorinate in order to render the water palatable.

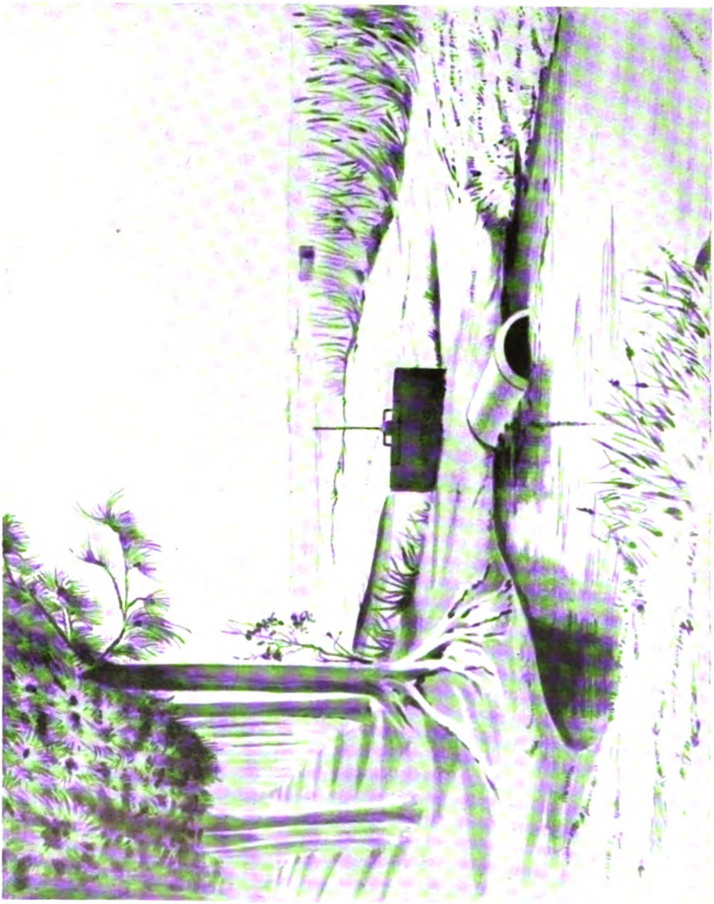

Fig. 2.—Rifle range canal at Tel-el-Kebir, where troops became infested with *S. mansoni* and *S. haematobium*.

The lesson to be learnt from these experiments was that a safe water supply could be obtained by allowing the water to stand for two days in improvised tanks made of tarpaulins; otherwise water should be sterilized by boiling or by the

addition of tablets of acid sulphate of soda. Water for ablution purposes could be rendered safe for immediate use by adding "cresol" in the dilution 1 in 10,000.

Researches on schistosomiasis affecting troops in Egypt were carried out by Major P. Manson-Bahr, R.A.M.C., and Lieut.-Colonel N. Hamilton Fairley, A.A.M.C. These officers produced the disease artificially in twenty-four monkeys, four being infected with *S. haematobium* and twenty with *S. mansoni*. In two, infection was produced by the drinking of infected water, in six it was produced through the skin, and in the remainder through both skin and mouth. A feature of these experiments was the marked pruritis produced by the infection, sometimes simulating the preliminary itching of which many soldiers complained after bathing in an infected pool at Tel-el-Kebir. (Fig. 2.)

TABLE I.

Seasonal Incidence in Infestation.

Month.	*Bullinus.*		*Planorbis.*	
	Number of Snails Dissected.	Percentage Infested.	Number of Snails Dissected.	Percentage Infested.
1917.				
May	51	1·9	280	37
June	27	0·0	572	19
July	140	0·7	288	29
August	57	1·7	567	8
September.. ..	93	0·0	689	10
October	No record.	No record.	920	6
November ..	50	4·0	1,468	30
December	362	9·0	379	54
1918.				
January	140	0·0	150	24
February	72	3·0	100	10
March	69	0·0	252	32
April	41	2·5	124	28
Total * ..	1,102	1·9	5,789	18

* These percentages have been worked out from the total number of specimens found infested each month.

Other experiments which were carried out included the dissection of snails obtained from the same locality for a period of twelve months. As a result of these dissections the above officers state that the largest number of snails harbouring cercariæ of both forms occurred in the late autumn. (Table I.)

They note that during April and May, when the canals are flushed with a large volume of water, the maximum breeding of *Planorbis* takes place, and that large masses of young *Planorbis* adhere to the weeds and rushes in the stagnant water; and if these are situated near villages there is a great likelihood of their becoming infected by miracidia. The breeding time of the *Bullinus*, on the other hand, seemed to be during the months of July and August, when the water of most of the smaller canals was at low ebb.

In summarizing their results they state "that while the month of maximum infectivity for both species of bilharzial cercariæ was December, there was definite evidence to prove that endemically areas are potentially infective throughout the whole year."

These officers had occasion to examine several cases of schistosomiasis admitted to hospital principally from the Australian Light Horse during October and November 1916, and their findings are shown in Table II.

This table is important in that it confirms Leiper's work. The clinical histories of the individual cases were interesting, as they brought out the fact that the men were not infected when swimming or bathing in rapidly flowing water, but when they bathed in weedy, stagnant pools or watered their horses in such places.

In determining the value of preventive measures these officers estimated the proportion of available chlorine required to kill the cercariæ. It is stated in the "Memoranda on some Medical Diseases in the Mediterranean War Areas" that one part of available chlorine per 1,000,000 parts of water was sufficient.* Manson-Bahr and Fairley, however, found the cercariæ alive after two and a half hours' immersion in water containing 4 parts per 1,000,000 parts of water, and they suggested that if sterilization by this method was to be carried out efficiently, a greater proportion of available chlorine must be used and followed by some method of dechlorination.

* This error was corrected in the second edition published.

TABLE II.

Canal Zone.	Infective Bathing Areas.	Troops Affected.	Total No. of Cases.	Type of Infestation.			Species of Snail found in Pool and Locality.	
				Schist. mansoni.	*Schist. haematobium.*	Double Infestations.	*Planorbis.*	*Bullinus.*
Zag-a-zig to Ismailia	Tel-el-Kebir	Australian Light Horse.	49	6	10	33	Present.	Present.
Zag-a-zig to Ismailia	Abou Soueir	,,	6	—	4	2	,,	,,
Kantara to Suez ..	Serapeum ..	,,	14	—	—	14	Absent.	,,
Upper Egypt ..	Deirut ..	,,	11	—	11	—	,,	,,
Upper Egypt ..	Fayoum ..	Imperial Mounted Yeomanry	6	—	6	—	,,	,,

Note.—The actual pool at Deirut, in Upper Egypt, was not investigated, but reference to the literature shows that snails of the ***Bullinus*** species are found there, but not those of ***Planorbis***. McCallan (1915) was able to show a 25 per cent. infection with *S.* ***haematobium*** in the country district around Deirut.

Mrs. Elgood, Medical Officer to the Ministry of Public Instruction, Cairo, and Major Cherry, of the Australian Army Medical Corps, conducted some investigations in Egypt on behalf of the Australian troops. The clinical histories of the infected men examined confirm the statement of Manson-Bahr and Fairley that men became infected while bathing or swimming in stagnant pools, and not after bathing in the flowing waters of the river. They advocated the use of domestic ducks as a preventive measure, first suggested by Keatinge at a lecture in Cairo in 1916. They state that if ducks are placed in a pool of water they very quickly eat up all infected snails and cercariæ. This is further borne out by the work of Cawston, in South Africa, who found that after allowing several domestic ducks to inhabit a pond he was unable to recover any infected molluscs, although previously he had always succeeded in discovering infected specimens. Mrs. Elgood and Major Cherry note that domestic ducks are of greater value than ordinary wild ducks, as the latter are easily disturbed and in their flight are apt to convey infection to fresh areas.

Chandler, Cawston and Milton also draw attention to the fact that certain chemicals, notably copper sulphate and lime, have a deleterious effect on the infected molluscs and may be used as preventives in local ponds. Cawston also states that he has traced the infection to the eating of watercress grown in an infected area.

It is interesting to consider the carrier question in connection with schistosomiasis. Troops and Egyptian Labour Corps were being transferred to other forces operating in different countries, and the possible infection of troops in previously uninfected areas by means of carriers from Egypt was feared by the medical authorities. This is borne out by the official communications which passed between Army Headquarters in Egypt and the War Office.

When a sharp epidemic broke out amongst the personnel of No. 22 Indian General Hospital, Basra, the D.M.S. of the force reported as follows: "The outbreak of bilharziasis at No. 22 Indian General Hospital is limited to the Indian personnel of that unit. It shows the risk of employing labour corps recruited in endemic centres of disease, and the possibility of introducing foreign diseases into a country previously free of them." This, however, was not the case, as Sturrock in 1899 gave evidence of schistosomiasis occurring amongst the native population in Mesopotamia, and the Medical Advisory Committee in January 1917 advised the D.M.S. that the disease

was not uncommon amongst the native population in the 15th Indian Divisional area around Nasiriya.

Captain C. L. Boulenger, the protozoologist to the Mesopotamian Expeditionary Force, was asked to investigate the outbreak, and to make a survey of the mollusc distribution

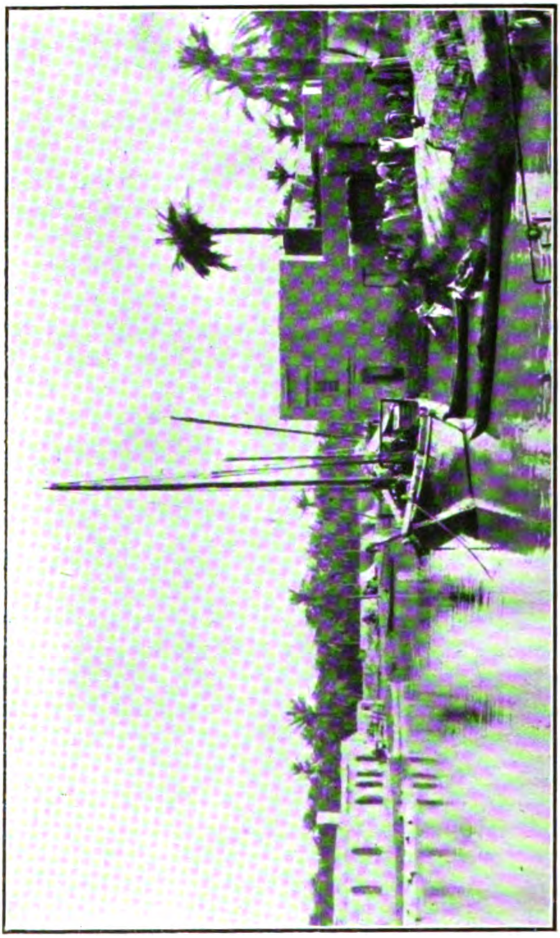

Fig. 3.—Khandaq Creek.

in the Tigris and Euphrates areas with a view to discovering the intermediary molluscan hosts of the parasite. The outbreak at No. 22 Indian General Hospital occurred at the beginning of November 1917. The infection was confined to the Indian

personnel and a few Arab *bellumshies* attached to the hospital. The personnel infected were 9 cooks, 8 *dhobies* or washermen, 6 *bhisties* or water carriers, 13 sweepers, 20 men of the Army Bearer Corps, 8 ward orderlies, 2 storekeepers, 1 *mistri*, 1 guide, 1 bullock driver, 1 havildar, and 1 clerk. Only three of these men had previously served in Egypt. The hospital was situated on the Khandaq Creek (Fig. 3), 100 yards from the Shatt-el-Arab, in the Ashar suburb of Basra. On the other side of the creek the labour corps were encamped and one site had recently been occupied by the Egyptian Labour Corps. The *dhobie ghât* of the hospital was situated on the creek just below a ferry much used by the Arab population for drawing water and for washing purposes. Naturally this area had been fouled by the insanitary habits of the Arabs. Behind the hospital there was a pool overgrown with water-weeds, the result of the inundation of water during the flood season.

Two sources of infection were suspected, the Egyptian Labour Corps and the native Arab population of Basra. Fifty-six *dhobies* and 38 *bhisties* belonging to two other Indian hospitals in Basra were examined, but no cases of schistosomiasis were found. Fifty male Arabs of the Ashar district were also examined, and 18 per cent. were found to be infected with the *haematobium*.

Further enquiries amongst the Arab population of Mesopotamia showed that this disease was widely distributed. The distribution is shown in the following table :—

TABLE III.

Table showing the Distribution of Schistosomum haematobium *among Arabs in different Districts of Mesopotamia.*

District.	No. of Arabs examined.	No. of Positive Findings.	Percentages.
Basra	50	9	18
Qurna	13	11	85
Amara	30	6	20
Baghdad	24	2	8
Samarra	20	2	10
Felujah	17	6	35
Ba'quba-Shahraban ..	20	—	—
	174	36	20

The conditions in certain parts of Mesopotamia are ideal for this disease. The Rivers Tigris, Euphrates, and Shatt-el-Arab

overflow their banks at certain seasons of the year and flood the country, especially in the swampy area around Basra, around Qurna, and towards Amara, and at Suk and the marshy ground above Nasiriya. (Fig. 4.) As fresh-water snails are liable to occur in any permanent collection of water, provided this harbours sufficient vegetation, it was natural to find

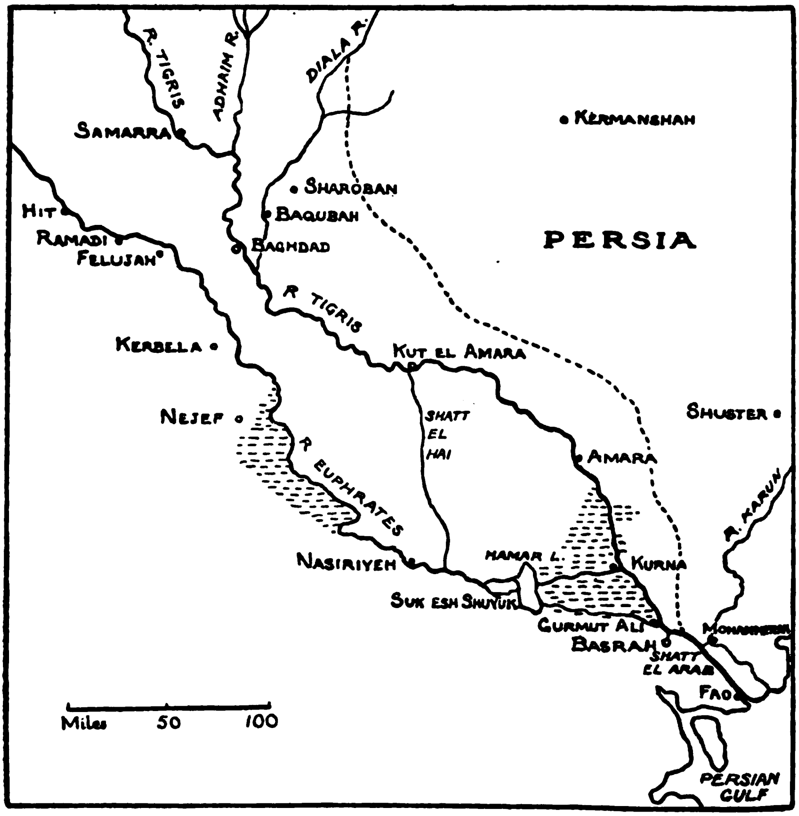

Fig. 4.—Map of Tigris, Euphrates and Shatt el Arab. Shaded areas show the marshy districts.

specimens in the marshy ground and in the network of creeks and ditches, but not in the swiftly flowing rivers and main canals. Near Basra in the higher reaches of the creeks and in the numerous pools and irrigation channels communicating with them, the vegetation was abundant and *Limnaea* and *Planorbis* were extremely common. *Melania tuberculata* and

Melanopsis were also found. At Qurna and in the Nasiriya-Suk district the fauna was the same. No further specimens of *Bullinus* were discovered in any of these localities. It is interesting to note that no infected specimens were discovered. At Amara a species of *Limnaea* and a few fresh shells of *Bullinus contortus* were found in a dry irrigation channel and in a dry marsh. Empty shells of *Bullinus contortus* were also obtained in the canals of Ramadi, and many in a semi-fossilized condition were found on the banks of the Tigris and Euphrates.

The survey was therefore disappointing ; it is important to note that in August 1918 the Indian Government offered to send two protozoologists to Mesopotamia to investigate further the molluscan fauna of that country.

Very few cases of schistosomiasis were reported amongst the combatant troops in Mesopotamia. So far as the records show, the total number admitted to hospital was only fifteen. Major-General A. P. Blenkinsop, the D.M.S. of the Mesopotamian Expeditionary Force, in May 1918 issued to all medical officers attached to the force a short memorandum on schistosomiasis. He drew attention to the distribution of the disease, the fauna of the country, the life-history of the parasite, the symptoms and diagnosis of the condition, and advised the following preventive measures :—

" All contact with untreated water from marshes, creeks, and irrigation channels should be avoided. This applies especially to the Euphrates basin from Qurna to Felujah, and the Tigris basin from Qurna to Amara. Water from the main river is far less likely to be infected and, where possible, should be used for all purposes. As the infective larvæ (*cercariae*) of *bilharzia* do not remain alive in water for more than 36 hours, any water stored for 48 hours may therefore be considered quite safe.

" Chlorination of water, as usually carried out, does not kill the larvæ ; ablution water may, however, be rendered safe by the addition of ordinary cresol in the dilution of 1 in 10,000 (one teaspoonful to two kerosene tins of water)."

In the campaign in East Africa numerous troops and departmental corps were sent from South Africa. It was natural to anticipate one or two outbreaks of schistosomiasis in this country, but so far as is known at the present time only a few isolated cases were recorded.

In France, Major-General Sir Wilmot Herringham reported three cases from the 9th Division. Two of the men belonged to the South African contingent and one to the 8th Black Watch.

As regards the cases occurring amongst the Egyptian Labour Corps in France, it was estimated that 75 per cent. of the class from which this labour corps was drawn were suffering from some form of schistosomiasis. . It was therefore difficult to exclude men suffering from this infection on enlistment. The important point to be decided was whether infected cases should be isolated or sent back to Egypt. Serious cases who were unfit for work owing to anæmia and debility were repatriated ; but it was found useless to attempt to isolate all cases, and it was sufficient to maintain sanitary discipline amongst the men and to prevent indiscriminate urination. As the Egyptian labourer was able at home to carry on his work in spite of the disease, it was found better not to pay too much attention to the sufferer, unless he had hæmaturia or cystitis to a noticeable degree.

Preventive measures to be adopted are clear and distinct, and must include treatment of the infected person, and general and local measures.

With regard to the treatment of the infected man, until a short time ago no treatment was of any avail. The method suggested by McDonagh, amplified by Christopherson and Newlove and adopted by Low and Newham, of treating cases by intravenous injections of antimonium tartaratum, presents a more hopeful prospect for the future. Injections of ½ to 2 gr. should be given, not oftener than twice a week, until a total of 16, 20½, 21 or 30 gr. has been injected.

The general measures include the provision, both for drinking and ablution purposes, of water which is free from infected cercariæ. This can be affected in the former case by storage of the water for two days, or by sterilizing it with bleaching powder and subsequent dechlorination. Ablution water can be rendered sterile by the addition of liquor cresoli saponatus, 1 c.c. to 2 gallons of water, which kills cercariæ in ten minutes. The same quantity in 4 gallons is effective in thirty-five minutes.

The general measures must also include strict orders prohibiting troops from frequenting or bathing or watering horses in pools of more or less stagnant water in endemic countries where the intermediary hosts of the parasite may occur.

As regards the local measures, any that tend to do away with such pools by drainage, removal of weeds, or destroying the molluscs and infected cercariæ should be adopted. The water may be cleared by the use of chemical manures, such as lime and ammonia, which have the additional property of benefiting the land, or by employing pure chemicals such as

copper sulphate, of which 1 part in 500,000 is sufficient to destroy most snails and with them the schistosomum parasite.

The use of the domestic duck as a preventive measure has already been referred to. The idea of employing ducks in a war area is not likely to find favour, as they might be a means of attracting troops to the infected spots; but it should be remembered that the Mesopotamian Expeditionary Force were able to organize a large poultry farm and several subsidiary farms for the purpose of supplying not only fowls but turkeys, geese and ducks, for the use of hospitals and messes in that country. But, while ducks would undoubtedly be of value locally in the prevention of schistosomiasis, it is doubtful whether Egypt could be freed from infection by their use, as has been suggested.

In conclusion, it is not out of place to refer briefly to the work of Chandler, who points out that while dissolved copper sulphate can conveniently be spread over small pools and thus destroy the *Bullinus*, *Pyrgophysa*, *Planorbis* and *Limnaea*, running streams can also be treated by using a barrel of suitable size fitted with a screened spigot. The barrel can be filled with water and sufficient copper sulphate dissolved in it, so that the desired amount may be fed into the running stream per hour. For this it is necessary to determine the rate of flow of the water and to calculate the correct amount of copper sulphate to be dissolved according to the average rate of flow. He believes that, by attacking the intermediary hosts of the various pathogenic flukes of man and domestic animals in this way, trematode disease can successfully be brought under control, and can either be greatly reduced or entirely eliminated in endemic areas. The expense would be small and the active co-operation of natives would not be required.

Water treated with copper sulphate sufficient to destroy the snails is uninjured for drinking, bathing, or irrigation purposes.

In connection with the treatment of schistosomiasis by intravenous injections of antimonium tartaratum, an interesting statement was published in the *Times* of 13th April 1922. According to medical records, 161 Australian soldiers who had contracted the disease in Egypt were returned to Australia apparently chronic invalids. The Federal Health Department, which has had control of 154 of these men, claimed that by the revised method of treatment 145 cases have been cured. Five were still under treatment, two could not be traced, and two refused treatment.

BIBLIOGRAPHY.

Boulenger ..	.. Report on Bilharziasis in Mesopotamia.	Ind. Jl. Med. Res., 1919–20, Vol. vii, p. 8.
Cawston ..	.. Bilharzia Infection in the Pool, the River and the Lagoon.	Jl. Trop. Med. & Hyg., 1922, Vol. xxv, p. 16.
" ..	.. The Control of Bilharzia ..	Brit. Med. Jl., 1921. Vol. i, p. 479.
Chandler ..	.. Control of Fluke Diseases by Destruction of the Intermediate Host.	Jl. Agric. Res., 1920. Vol. xx. p. 193.
Christopherson	.. Intravenous Injections of Antimonium Tartaratum in Bilharziasis.	Lancet, 1918, Vol. ii, p. 325.
" ..	.. Antimony in Bilharziasis ..	*Ibid.*, 1919, Vol. i, p. 79.
Cottell ..	.. Notes on Cases of Bilharzia Hæmatobia collected at the Royal Hospital, Chelsea.	Jl. of R.A.M.C., 1912, Vol. xviii, p. 434.
Elgood & Cherry	.. Bilharziasis, its Incidence and Eradication.	Lancet, 1919, Vol. ii, p. 636.
Leiper ..	.. Report on the Results of the Bilharzia Mission in Egypt.	Jl. of R.A.M.C., 1915, Vol. xxv, pp. 1, 147, 253; 1916, Vol. xxvii, p. 171; 1918, Vol. xxx, p. 235.
Looss ..	.. Recherches sur la faune parasitaire de l'Egypte.	Inst. Egyptien, Pt. 1, pp. 2, 64, 158–166, 204–210 (1896).
Low & Newham	.. A Series of Cases of Bilharziasis. Treatment by Intravenous Injections of Antimonium Tartaratum.	Lancet, 1919, Vol. ii, p. 633.
McDonagh ..	.. Antimony in Bilharziasis ..	*Ibid.*, 1918, Vol. ii, p. 371.
Manson-Bahr & Fairley.	Observations on Bilharziasis amongst the Egyptian Expeditionary Force, with Suggestions for Prophylaxis.	Parasitology, 1920, Vol. xii, p. 33.
Milton ..	.. Bilharziasis, its Incidence and Eradication.	Lancet, 1920, Vol. i, p. 196.
Narabayashi	.. Contribution to the Life History of Schistosomum Japorimum	Trop. Dis. Bull., 1917, Sept., Vol. x, p. 113.
Newlove ..	.. (See Christopherson).	
Simpson ..	.. The Medical History of the South African War.	Jl. of R.A.M.C., 1910, Vol. xv, pp. 18, 257, 394, 533, 659.
Sturrock ..	.. Bilharziasis in Mesopotamia ..	Br. Med. Jl., 1899, Vol. ii, p. 1543.
Official ..	.. Memoranda on some Medical Diseases in the Mediterranean War Areas with some Sanitary Notes.	War Office Publication, 1916.

CHAPTER XV.

PREVENTION OF TRACHOMA.

THE introduction of coloured labour into France brought about an interesting problem of dealing with trachoma on a large scale. This disease was found to exist amongst the Chinese, the Egyptians and the Cape Boys in varying proportion; and though the percentage of incidence was comparatively low except in the case of the Egyptians the aggregate number of cases ran into many thousands.

Trachoma is transmitted by contact with the ocular discharge, and therefore spreads most rapidly, as would be expected, when it occurs in communities living in close touch, where towels, blankets and handkerchiefs are readily interchangeable.

It was early recognized by those responsible for sanitation in the army that with the proximity in which the individuals of the labour corps must necessarily live, and the wide dissemination of the disease amongst the coloured units, there was a grave danger of trachoma becoming practically universal throughout these units. Had this occurred their capacity for work would have been greatly impaired, and there would have been a considerable risk of the disease spreading to the British troops and to the French population. It is also likely that a widespread dissemination of the disease by the coolies would have taken place on their repatriation to the districts from which they had been recruited, similar to the outbreaks that occurred in Belgium early in 1800 on the disbandment of its army, and in France on the return of the troops from the Egyptian campaign in the time of Napoleon. Experience of trachoma in the labour corps in France proved that the disease untreated could spread rapidly and that it crippled labour.

The infectiveness of the disease was clearly shown in two Chinese companies, the first examination of which revealed twelve cases in one and fifteen in the other. Owing to the importance of the disease not being recognized by the local authorities, the notified cases of trachoma were not removed and no treatment was carried out, and in eight weeks' time there were fifty-nine cases in one company and eighty-one in the other. If such dissemination occurred in eight weeks,

it was reasonable to suppose that, if no treatment throughout had been adopted, in a year's time nearly all the Chinese in France would have been trachomatous.

The incapacitating effect on labour was well demonstrated in another company, which was made up of men all of whom had trachoma, and which was sent to an army area for about six weeks. During that time no treatment was carried out. At the end of the six weeks the average number of men off duty daily for eye trouble was about thirty, and fifteen men had been sent to headquarters as unfit to work. Here, again, it was reasonable to expect that if no treatment had been adopted a very high percentage of the coolies would have been unfit to work, and many of them would have lost their sight.

Owing to the intractable nature of trachoma, which under the best conditions needs from six months to two years of regular treatment to effect a cure, it could not be hoped to stamp out the disease and render each case infection-free.

The practical problem was to ameliorate as far as possible the condition of those who had trachoma, to keep them fit for work, and to prevent the spread of disease to the British troops, the French population, or to the unaffected men of their own unit.

By the methods adopted satisfactory results were obtained. In a report drawn up after fifteen months of experience it was stated that though there had been some 8,500 cases of acute infectious trachoma, 5,500 cases of suspicious conjunctivitis, and 86,000 contact cases, the disease was diminishing, the individual cases were greatly improved, no instance was reported of the disease having spread from the coolies to the British troops or to the French population, and the number of men off duty daily for eye trouble was from 0·025 to 0·09 per cent., and this was no greater in the trachoma companies than in the clean companies.

The disease was originally discovered amongst the coolies in France, first in the Egyptian and later in the Chinese companies, and with the co-operation of the adviser in pathology and the A.D.M.S. for sanitation thorough treatment of the disease was immediately advised by the consultant in ophthalmology. It was decided to take steps to prevent as far as possible the introduction of further cases into France, and to organize segregation and some form of treatment for those who had already arrived.

It was recommended that the following order should at once be telegraphed to Egypt and China, "no cases with definite

trachomatous granulations or any acute conjunctivitis should be allowed to embark from Egypt or China or to disembark in France." This instruction had a beneficial effect in China, for the percentage fell from 13 per cent. in the early batches to as low as 3 per cent. in the later ones. No doubt it was extremely difficult to get a sufficient number of coolies who were trachoma-free ; only a limited number of men were willing to enlist, and when recruited it needed a great expenditure of time on the part of surgeons expert in recognizing the disease to evert the lids of each man and to reject every definite or even suspicious case, but had this been done from first to last there would have been no trachoma problem in France.

It was noted that amongst the Chinese there was a large number of very early cases as well as those of old standing, and it was suspected that many of the men with the slighter signs had started from China clean, but had become infected on the voyage. In order to prevent this infection as far as possible, a later message was sent to China from the War Office urging that coolies with trachoma should be isolated as far as possible on board ship.

In spite of these precautions large numbers of men from both China and Egypt arrived in France with the disease, though, as mentioned above, in the later batches there was great diminution of incidence among the Chinese.

The second step was to organize some scheme of segregation and a course of treatment for those who had arrived. At first it was thought that the infected men in each company could be segregated from their fellows without breaking up the companies themselves and that the coloured companies could all work in a few definite centres where treatment might be carried out. It was soon found, however, that labour companies were needed all over the British area, and this rendered treatment in each company impossible, for trachoma can only be satisfactorily dealt with by medical officers with ophthalmic knowledge, and of these there were not nearly enough for the purpose.

A new scheme had, therefore, to be formulated so as to group the affected men together. The broad principles followed were :—

(1) To comb out and group the affected men into separate companies (trachoma companies) where the men could sleep, wash, and work together without risk of spreading the disease to the unaffected.

(2) To limit as far as possible ocular discharge by appropriate measures, and to treat the individual cases.

(3) To sterilize at frequent and regular intervals the towels both in the clean and dirty companies, so that if these were exchanged from man to man, the risk of passing on any infection that might be lurking in a towel would be reduced to a minimum.

(4) To organize periodic inspections of the clean companies.

The Egyptian labourers were highly affected with the disease, for at a low estimate 45 per cent. were either suffering from or had had trachoma. From the point of view of treatment they were difficult to deal with, as they could not or would not work except under their own *rais* who had recruited them from their own villages, and thus trachoma companies could not be formed.

Treatment had, therefore, to be carried out in each company as far as possible, but trachoma being endemic in Egypt and the incidence of the disease there being high, the responsibility with regard to the unaffected was not so heavy; also the fact that the Egyptian labour companies were comparatively few in number and were returning to Egypt in the course of a few months made the necessity for complete organization less important. They improved very considerably with treatment, fewer men were off duty for eye trouble, and the quality of their work was much better, as was borne out by the testimony of their non-medical officers.

Cape Boys, who were enlisted in the Auxiliary Horse Transport, were a comparatively small body and only 3 per cent. were found to be trachomatous. These were all combed out and placed in a separate section which worked, slept, and washed together, and where they were all treated. By these means the least possible disturbance was caused to the work of this unit.

The main problem was with the Chinese, who were expected to stay for some years and of whom there were roughly 100,000 working for the British in France. The incidence among them was about 8 per cent., the number of trachoma cases being about 8,500.

The scheme of treatment was gradually evolved and improved and its adoption worked with satisfactory results.

In the preliminary segregation of the affected coolies there were two separate problems: there was the separation of the infectious cases as the men arrived in France, and, what

was more difficult, the combing out of the infectious cases from each of the companies which had already been sent out and were working in various parts of the British area.

All men arriving at Chinese headquarters had their eyes examined by experts, but in this inspection considerable difficulty in classification arose. Conjunctivitis is rife among the Chinese, especially in those who work in dusty localities, and there being no definite pathological tests as to whether a given case of conjunctivitis is or is not trachoma, the diagnosis rests on clinical experience. Until a trachomatous conjunctivitis has developed characteristic clinical signs it is impossible to discriminate between the two, and it was found that numerous cases of conjunctivitis were met with which were of doubtful nature. If these cases had been kept at headquarters at Noyelles until the diagnosis was substantiated, many weeks of labour would have been lost. Again, if a man with a non-trachomatous conjunctivitis was placed in a trachoma company he would almost certainly acquire trachoma, while if a trachoma case was placed in a clean company he would be a centre of infection. It was therefore decided that three sets of companies should be formed :—

X, "clean," companies, containing the apparently unaffected cases,

Y companies, containing cases with conjunctivitis of doubtful nature, and

Z trachoma companies, containing cases of undoubted trachoma.

At the preliminary examination each man was classified as X, Y, or Z, and placed in a corresponding company. It should be noticed here that the so-called "clean companies" were formed of men who in reality were all "contact cases"; for the men came over in ships closely crowded together and probably used towels and blankets indiscriminately, and many of these, though apparently clean on first inspection, might develop trachoma later, a fact which indicated the importance of regular periodic inspection.

The clean companies could be sent wherever they were needed, under the supervision of medical officers who had not necessarily had ophthalmic training.

The Y and Z companies were sent to certain definite places, designated "trachoma treatment centres," where they were under the supervision and treatment of an ophthalmic specialist. It was strongly urged that such companies should

not be sent up country, for there they could seldom get skilled treatment or supervision.

Trachoma treatment centres were therefore formed at Calais, Vendroux, Boulogne, Dannes-Camiers, Saigneville, and later one was started at Abancourt.

If a new trachoma treatment centre were required it was urged that the Z companies should be so grouped that at the centre there were not less than 2,000 cases, in order that a whole-time ophthalmic specialist could be appointed to look after them, since a smaller number would not have fully occupied his time.

The labour of inspection of the men arriving in their thousands at headquarters was very great. Meticulous care at this stage was obviously all important, and had it not been for the untiring and thorough work of the medical officers, Captains Stuckey, C. A. Hughes, and Tomlin, with the whole-hearted and efficient co-operation of Lieut.-Colonel G. D. Gray, the officer commanding No. 3 Native Labour Hospital at Noyelles and medical adviser to the Chinese, the whole scheme would have been a failure.

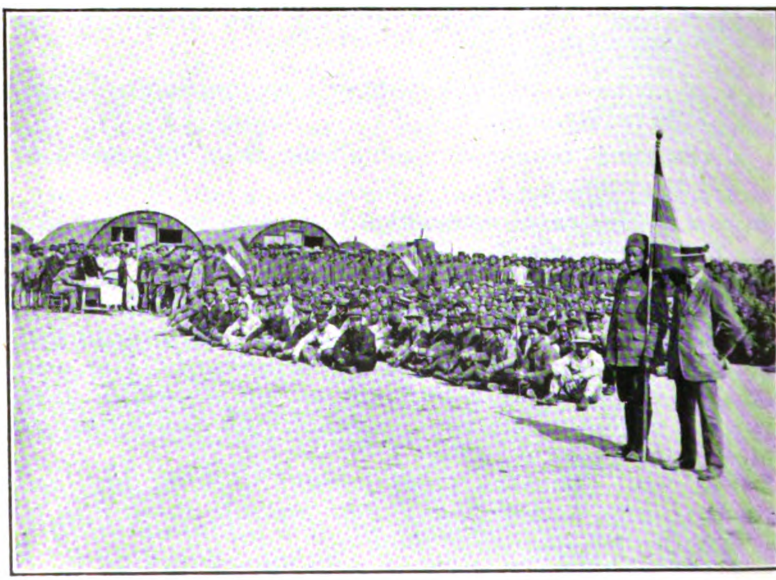

Fig. 1.—Inspection parade. In the background, rows of Chinese are coming up to the examining medical officers. On the left, the recording officer at the table is noting the classification. In front, the men are awaiting examination.

Before any steps had been taken to combat the disease there were already in France numerous mixed companies of men, some affected and some clean, and these were scattered over a wide area. It was necessary, therefore, to visit and inspect all these companies and comb out the infectious cases, who were then either sent back to Chinese headquarters or to a neighbouring trachoma company.

The inspection of these men already at work was also laborious; it lasted over many weeks and involved a great deal

Fig. 2.—Inspection parade. Shows the four examining medical officers and the recording officer at the table, at the far side of which a Y or Z case is having his identity number taken from his brass wrist-band. On the table are seen the bowls of disinfectant and towels.

of travelling. Every man in each company had both lids everted and was classified X, Y, or Z, and the identity numbers of the Z and Y cases were taken. The Y cases were treated in their own companies, and the Z cases sent to headquarters to be placed in trachoma companies. On one day 11,000 lids were turned and the corresponding 5,500 coolies were classified. This was carried out chiefly by Major Cunningham, Major Derby (ophthalmic consultant to the American Expeditionary

Force), Captains Wharton, Whiting and Stirling, and the consulting ophthalmic surgeon.

Inspection Parades.—The examinations were made at times arranged to suit the labour authorities so as to obstruct work as little as possible, and were therefore chiefly made on Sundays when the men generally had a day off. It is understood that in

NATIONALITY - Chinese LABOUR COY. NO. - 73

LOCATION - Isbergues DATE - Sept. 30. 1917.

	Z	Nos.	Y	Nos.	X	X	
1		10752		59221			
2				59635			
3				59660			
4				58927			
5				54908			
6				57025			
7				54571			
8				208			
9				54799			
10				57665			
11				55139			
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
					240	209	
	1		11		449		TOTAL NUMBER EXAMINED - 461

Fig. 3.—Specimen record of inspecting examination.

spite of the large numbers examined only a very few hours of work were encroached upon by these inspections.

On arrival of the inspecting officers at the camp the men were formed up in three or four rows corresponding with the number of examining medical officers and came up in turn for inspection.

(Figs. 1 and 2.) At a table, just behind the examining officers, a recording officer sat who made notes in duplicate of the examination. (Fig. 3.) A dot was made for each case examined in the appropriate X, Y, or Z column. The X cases after examination were allowed to fall out at once, but the Y or Z cases were handed on to a N.C.O. who took the man's number from his brass identity disc or wristband and called it out to the recording officer who noted it. On the table were bowls of disinfectant and towels for cleansing the hands of the examining officers after touching an infectious case. The examination of a company of 500 men by three medical officers and one recording officer took as a rule from twenty-five to thirty minutes working rapidly.

At the end of the examination one had, therefore, a record of the total number of men seen, and the identity numbers of the men who had trachoma and of those who had suspicious conjunctivitis. A copy of the record was left with the company officer, who saw that the Z cases were sent to headquarters, and that the Y cases were specially treated by their own medical officer. If any Y case later developed severe signs he was sent to headquarters.

Limitation of the Infective Matter.—Every Chinese coolie, whether clean or infected, had some eye treatment every day.

X, "Clean," Companies.—As previously stated, conjunctivitis is exceedingly common amongst the Chinese; many have long-standing inflammation, with reddening and some amount of thickening of the conjunctiva, but without granules, scarring, or pannus. Such a condition, under the irritating influence of dust from heaving coal or hay, or working on the docks or in the sand, is liable to exacerbation and readily becomes complicated with catarrhal ulceration of the cornea.

It was important that such cases should have the conjunctiva washed out daily with some astringent antiseptic lotion, which would keep it healthy and limit the discharge. The eyes of those without any conjunctivitis were none the worse, indeed, were all the better for daily irrigation.

The "daily drop treatment" was carried out in a very simple way. It was always done in the men's off-time, so as not to obstruct labour, and the medical officer kept a careful time-table in order to arrange for the regular treatment of the different batches of men in off-duty hours.

The batches of off-duty men, or when possible the whole company, were lined up in two rows. (Figs. 4 and 5.) The men squatted on their heels, a common position of rest among

orientals, a ganger stood behind, supporting the head and raising the upper lids, while the man pulled down his own lower lids. The medical orderly with a jar of lotion in his left hand, and an ophthalmic dropper in the right, inserted a few drops *seriatim* in the two eyes. The ganger and orderly, a pair to each row, passed down the line from man to man. In this way the drop treatment was carried out so rapidly that the whole 500 could usually be treated in from ten to fifteen minutes; the treatment

Fig. 4.—"Drop parade." The men are squatting in rows. The ganger stands behind supporting the head and lifting the upper lids, while the man pulls down the lower lids; the medical orderly meanwhile instils the drops.

was thus neither laborious nor did it occupy much time. The men recognized its value and often resented being accidentally overlooked; some, indeed, asked for a second application.

Any case with corneal ulceration or muco-purulent discharge in an X company was treated separately with atropin or by painting with nitrate of silver solution, etc., as was necessary.

The astringent drops used were an aqueous solution of boric acid grains 10, zinc sulphate grains 2 to the ounce. Very marked improvement of the coolie's eyes took place as soon as this universal drop treatment was adopted.

Y Companies.—These companies, as already stated, were formed of men all of whom had conjunctivitis of a suspicious character at the preliminary examination at headquarters; it was to be expected, therefore, that some of these would develop definite trachoma. Treatment was carried out on much the same plan as in the X companies, but the more severe

Fig. 5.—"Drop parade." Enlarged view of exact method of instilling the drops.

cases with definite conjunctival discharge were regularly painted with some silver solution (silver nitrate or protargol) until the discharge ceased.

Cases which had developed trachoma were combed out and sent either to headquarters or to a neighbouring trachoma company. The detection of such cases needed the experience

of an ophthalmic specialist, and it was for this reason that the Y cases were placed at trachoma treatment centres. An untrained medical officer might either have become too easily alarmed, and by fearing every inflamed eye to be trachomatous, broken up a company unnecessarily, or by overlooking infectious cases might have allowed a considerable spread of the disease.

Z, Trachoma Companies.—These, like the Y companies, were placed at trachoma treatment centres, and were under the care of ophthalmic specialists. In the worst cases the granules

Fig. 6.—"Drop parade" in a Y or Z company. Shows the medical officers examining the men, followed by the orderly with the drops.

were "expressed." Those with chronic thickening of the conjunctiva were treated with sulphate of copper crystal, or when there was discharge, with 2 per cent. silver nitrate solution; cases which were progressing favourably were given sulphate of copper drops or the boric and zinc solution; while complications such as keratitis or corneal ulcer were treated on ordinary lines. Severe cases unable to work were sent to hospital at headquarters.

The medical officer was advised to look through each Y and Z company every two weeks as opportunity offered. A good

plan was for him to do this at the "dropping parade," preceding the ganger and orderly and turning the lids of each case as he went down the line. In this way he was able to see how the men were getting on and could select any case for special treatment, or detect any case in a Y company which might have developed trachoma. (Fig. 6.)

Sterilization of Towels.—The towels wipe the discharge from the eyes and thus become infection-bearers. It has long been known that towels and handkerchiefs are a great source of

Fig. 7.—"Towel parade." Shows the men bringing up their dirty towels and being instructed to throw them into the boiler.

danger in trachoma, in fact, the roller-towel is said to have been the chief means of spreading trachoma in the British army in the past. The Chinese do not indulge in handkerchiefs to any great extent, but use their towels for every conceivable purpose.

With such large numbers it was at first difficult to arrange for the sterilization of the towels, and it was at the suggestion of Captain McMurray, who was in charge of the trachoma cases at Calais for over a year, that boilers were supplied to the companies, so that on stated days the men on returning from

work threw their towels into the cauldron, where they were boiled for half an hour, and meanwhile an issue of clean ones was made. (Fig. 7.) It was the rule that the towels should be sterilized twice a week, a procedure of great importance, but unfortunately this plan was not universally carried out, owing either to the difficulty of supplying boilers or to the shortage of fuel in certain districts. Sterilization of towels should, however, be insisted upon either by boiling or some other method.

Periodic Inspections of the Clean (X) Companies.—The X companies consisted of the cases which were found unaffected at the first examination, but, as already noted, they were all "contact cases," and it was therefore only to be expected that a proportion of them would develop trachoma later.

Periodic inspection of these X companies was therefore of great importance; their medical officers were not ophthalmic specialists and therefore had not the knowledge to recognize and comb out those who had developed trachoma, and the disease might easily thus arise and spread without detection.

The number of the so-called "clean" cases was so great, and the distributiom of the X companies so wide, that it was practically impossible for one or two senior ophthalmic officers to visit all these companies frequently, yet it was very important that they should be kept under ophthalmic supervision.

A system of ophthalmic report cards was instituted at the suggestion of Major Cunningham. (Fig. 8.) The reports sent in monthly were kept in a card index and showed the state of the companies. It was thus easy to look up the records of any company and note its ophthalmic state month by month, and if there had been much conjunctivitis or suspected trachoma in a given company it was visited; if no men were off work and there was little or no conjunctival discharge, regular visiting was unnecessary.

The whole British area was divided up into definite districts and regular inspection of the X companies was provided for; thus the ophthalmic specialists at Noyelles undertook the onerous work of inspecting all the army areas together with the Abbeville-Amiens area, while the companies in the Rouen, Le Havre, and Dieppe areas were supervised by the senior ophthalmic specialist of the corresponding base, and in the northern area of the L. of C. the supervision was under the control of the consultant.

FRONT

OPHTHALMIC REPORT

Date.. C. L. C. No.................. X. Y. Z.

Location...

Strength.................................Date Coy. left H.Q...

Nature of Work ....

Average no. of men off **DAILY** for Eye Trouble ....

No. of Trachoma cases sent to H. Q. in last month ....

of these the no. so severe as to be unfit for work ....

Is daily Treatment regularly carried out? ....

Are Towels sterilised twice a week regularly? ....

P.T.O.

BACK

X. Coy.	No. of Trachoma cases (if any)	....
	No. of cases with Conjunctival discharge	....
Y. Coy.	No. of Trachoma cases (if any)	....
	No. of cases with Conjunctival discharge	....
	No. of apparently cured cases	....
Z. Coy.	No. of **SEVERE** cases of Trachoma	....
	No. of **MILD** ,, ,,	....
	No. of apparently cured cases	....

Remarks..

....

Reports to be sent in **MONTHLY** to the Consulting Ophthalmic Surgeon, c/o D.D.M.S., Boulogne.

Signature of M. O.. P.T.O.

Fig. 8. Ophthalmic Report Card.

Transference of "Cured" Cases.—As already stated, trachoma is a very intractable disease; though under the most favourable conditions of supervision and treatment a complete cure can rarely be effected under six to twenty-four months, it may often take considerably longer; and it should also be noted that apparently "cured" cases are very apt to recrudesce under unfavourable conditions.

It was, therefore, highly inadvisable to take apparently cured cases from Y and Z companies and place them in X companies; that is to say, once in a Z company a man always remained in a Z company. Similarly, in the Y companies the apparently cured cases were in daily contact with a certain number of the trachomatous. Without a complicated system of observation compounds it would have been equally unwise to transfer these apparently cured cases to clean companies.

After the above treatment had been carried out it was rare to see any of the severe type that was so common on arrival, but the success of the treatment depended upon the care and perseverance of the medical officers. The trachoma specialists constantly bore witness to the improvement which took place in the companies under their care; and the company and administrative officers frequently expressed their appreciation of the improved quality and quantity of the work done by the men in consequence of the treatment.

That trachoma untreated leads to a great loss of work-power has already been mentioned, and by way of illustration it is worth while to give details of a trachoma company which was sent up to an army area, where it received no special treatment, and in consequence the disease assumed a virulent and incapacitating character. When in October 1917 this company was sent to the base and came under the supervision of Captain M. L. Hine, ophthalmic specialist at Dannes-Camiers, out of the 588 men 68 needed "expression" of granules, and there were many cases with severe muco-purulent discharge, and on the average 30 men were off duty daily for eye trouble. By December the average number off duty had fallen to 7 daily, while in January and February 1918 the average number off duty daily was down to 2, that is, 0·34 per cent. This improvement was due to the vigorous treatment instituted by Captain Hine together with the devotion of Captain T. L. Harrison, who during the cold winter months got up regularly at about 4 o'clock every morning to treat his company before they went to work. The moral of this instance is that a company neglected for some six

weeks took about three months to regain its full working efficiency.

Lieutenant J. A. C. Smith in Dannes-Camiers had equally good results owing to perseverance. When he first took over the treatment of two Z companies in November 1917 the average number off duty daily of the 1,000 men was twenty-five, while in the following year a period of four months elapsed without a single man being incapacitated from work because of his eyes.

Captain Horatio Matthews had also a fine record of his two trachoma companies at Vendroux, where amongst 1,000 cases, in April two were excused on account of their eyes, in May there were no cases, in June two, and in July there was only one case.

It was the conscientious work just recorded and that of many other medical officers which led to the satisfactory results obtained, namely, the prevention of the spread of the disease to British troops and the French population, and also the satisfactory effect on labour.

CHAPTER XVI.

PREVENTION OF SMALLPOX.

An outbreak of smallpox in the regular army prior to the commencement of the war was not viewed with alarm owing to the protection afforded by the increasing attention paid to the vaccination of personnel and to the disposal of smallpox cases and contacts. Every recruit was vaccinated on enlistment, and any man presenting himself for enlistment who refused to be vaccinated or revaccinated was not accepted. The vaccination or revaccination was performed on the second day after the recruit joined his depôt. The medical officer in charge of the depôt was responsible for this and for a correct entry being made in the soldier's medical history sheet and in the vaccination register. In cases where the revaccination of recruits failed, three successive operations were carried out at intervals of one week, in order to make certain that failure was due to acquired immunity. When this was so, an entry of the fact was made in the vaccination table in the medical history sheet.

TABLE I.

Command.	No. of Smallpox Cases.	Strength.
United Kingdom	—	119,766
Gibraltar	—	3,661
Malta	—	6,336
Egypt	1	5,618
Cyprus	—	114
Bermuda	—	1,252
Jamaica	—	380
West Africa	—	296
South Africa	—	6,703
Mauritius	—	1,166
Ceylon	—	330
South China	—	1,883
North China	—	1,936
Straits Settlements	—	1,376
India	14 (1 death)	70,755
On Board Ship	—	2,891

In March of each year medical officers on duty with troops satisfied themselves that every man, woman, and child under their care was sufficiently protected by vaccination, and on 1st April the D.D.M.S. of the command sent a return to the War Office showing the state of vaccination, and giving the results obtained.

That these measures were effective is proved by the statistics available each year. The incidence of the disease in the British army during 1913 is given in Table I.

The immunity therein shown was the result of the orders in force, and that they were carried out with the greatest care is shown by the numbers of soldiers, women, and children vaccinated or revaccinated in the same year, which were as follows:—

	Primary.	Revaccinations.	Successes, per cent.	
			Primary.	Revaccinations.
Soldiers and recruits ..	2,170	31,877	97·5	76·9
Women	83	1,397	96·4	79·9
Children	4,219	1,197	91·3	76·6

On the outbreak of war the Director-General of the Army Medical Service viewed with apprehension the addition to the ranks of a large number of inadequately protected men. The following circular was consequently issued :—

"The attention of all administrative and executive medical officers is directed to the grave danger of smallpox being introduced in epidemic form, especially among the troops of the Territorial Force mobilized in garrisons or camps, owing to the certainty that a large proportion of the men joining the force will either not have been vaccinated at all or will not have been revaccinated since childhood. No time should be lost in making a careful examination of all officers and men as soon as possible after mobilization, and of taking steps, with the consent of the General Staff, for the prompt vaccination of every man who does not bear recent marks of satisfactory vaccination."

In January 1916 Army Council Instructions were published authorizing the enlistment of men, even although they declined to be vaccinated. This opened a breach in the Army Medical Service fence of protection of the army against smallpox,

and it is important to record the results of employing unprotected British troops in theatres of war where smallpox was prevalent.

It is interesting at the outset to note the incidence of the disease amongst the civil population in the different countries in which allied and enemy forces were operating. Smallpox was prevalent in Russia during the war, and between 1914 and 1917 3,984 cases with 1,002 deaths were reported at Petrograd. The disease was also prevalent in Moscow, Odessa, Warsaw, and it broke out in Archangel and Vladivostok. It is probable that it was imported into Germany in 1916 by prisoners of war, as up to that time no cases had been reported. In December 1916, cases were reported from Schleswig, and the disease spread to the northern and southern states. In 1917 there were 2,300 cases, in December 1918 there were 500 cases in Berlin, and the outbreak subsequently spread to Saxony, East and West Prussia. During the first three months of 1919 there were 1,300 cases. A few cases did occur in the German army, but the disease never spread, despite the fact that when the German troops invaded Poland, smallpox was rampant amongst the civil inhabitants, and the German troops could not devote strict attention to the details of personal hygiene. This immunity in the German army is attributed to the fact that vaccination was thoroughly and efficiently carried out. The Germans had learnt their lesson by the year 1875. Prior to that date in the period 1860–64 the mortality from smallpox per 100,000 of the German population was 30·1 ; for the period 1865–69 it was 37·4 ; and from 1870–74 it was 113·7. On 1st April, 1875, vaccination was made compulsory for everyone in Germany, and the mortality ultimately diminished, as will be seen by the following figures :—

Period.	*Smallpox Mortality per 100,000 of the German Population.*
1875–1879	1·8
1880–1884	2·6
1885–1889	0·64
1890–1894	0·23
1895–1899	0·05

In Austria-Hungary during the last three months of 1914 there were 306 cases, while in 1915 the total number was 23,502. In 1916 there were 18,988 cases, and during the first half of 1917, 1,378 cases. After the armistice and up to the

end of the year 1918 there were 113 cases in German Austria, and from March 1919 onwards 191 cases were reported. There were very few cases in the Austro-Hungarian army, as here again strict attention had been paid to the vaccination and revaccination of recruits.

In Italy there was an outbreak of smallpox in the summer of 1918, but while it was prevalent in certain districts it did not spread to the Italian army, where vaccination was compulsory.

In France there were small outbreaks amongst the civil populations at Rouen and Marseilles. Up to the end of 1917 no case of smallpox was reported in the French army, and for the four years of the war there was a total of 12 cases, while 44 cases with 4 deaths occurred amongst the French colonial troops. The French had learnt their lesson in the campaign of 1870-71, when 125,000 French soldiers contracted smallpox, of whom 23,470 died. During the war of 1914–18 the French authorities paid particular attention to vaccination and revaccination, and Fasquelle, Director of the Anti-Smallpox Service of the French army, attributes the immunity which was enjoyed to compulsory vaccination of all ranks and to the free distribution of active lymph throughout France.

In England and Wales during 1916, 149 cases of smallpox were notified. In the borough of Cardiff alone there were 49 cases. In Egypt, East Africa, Mesopotamia, in the district around Constantinople and elsewhere, this disease was very prevalent. In fact, after the armistice it assumed pandemic proportions.

The incidence of smallpox in the British forces in France during the war was slight. In 1914 and 1915 there were no cases; in 1916 there were 4; in 1917 there were 2; and in 1918 there were 6 cases and 3 deaths. Several of these cases were imported from Egypt; the remainder developed the disease in France. The freedom of the British army in France, considering the large numbers of men who were unprotected by vaccination, must be attributed to the great care taken both by our allies and by the enemy to create a protected population in the midst of which unprotected British troops were safe.

In Egypt, Palestine, East Africa and Macedonia, although accurate figures cannot be given at present, there is enough evidence to show that the number of cases was comparatively small. In Italy during June and July 1918, cases of smallpox

were reported amongst British troops in nine different districts. When the Army of the Black Sea established itself around Constantinople in 1919, and came into contact with the civilian Turkish population, a sharp epidemic occurred amongst the British troops and 70 cases were reported. The spread of the disease was limited by efficient vaccination and revaccination.

In North Russia a case of smallpox occurred early in March 1919. The patient was a peasant woman who had passed from the Bolshevik lines to the British-American lines on the Vaga river. She was admitted to a local Russian hospital. Later one American and two Russian soldiers contracted the disease, whilst nine civilian cases were reported from a village not far distant from that in which the first case had been identified. All the cases were isolated in a Russian hospital, contacts were traced, put in quarantine and vaccinated, and all the inhabitants in the vicinity were also vaccinated. As far as military operations permitted, the infected area was circumscribed and controlled. British medical officers personally carried out the vaccination of no fewer than 6,000 individuals.

In spite of efforts to protect the tubes of calf lymph from the effects of low temperatures, the lymph appeared to be inert. It was received from England packed in thermos flasks and was distributed, similarly protected, to medical officers, who carried out the operation of vaccination in adequately heated buildings. The lymph was of recent date, and in no case had the time limit expired beyond which potency was doubtful.

In May 1919 a fresh epidemic broke out at Yemetskoe, a district some miles further north; all the cases proved to be refugees from the first area affected.

In Mesopotamia there was a serious outbreak, which will be dealt with at length. The total number of cases from December 1916 to October 1919 was 1,908, and Chart I shows the monthly incidence of the disease during that period. In dealing with this outbreak many difficult problems presented themselves, and if these are appreciated correctly the regulations regarding smallpox and vaccination require careful reconsideration. Mesopotamia, and particularly Baghdad, is one of the endemic homes of smallpox. It was through Baghdad in 1802 that vaccination first spread to India. The civil inhabitants of Mesopotamia, whatever may be their disrespect for preventive measures regarding other diseases,

have learnt the value of vaccination in smallpox. It is worthy of note that under Turkish rule civil vaccinators were allotted to the different districts, and that vaccination was readily accepted by the civil inhabitants. During the British occupation in 1914–15 and 1916 this system had been in abeyance.

The prevalence of smallpox in the country was first brought to the notice of the D.M.S. by the Medical Advisory Committee

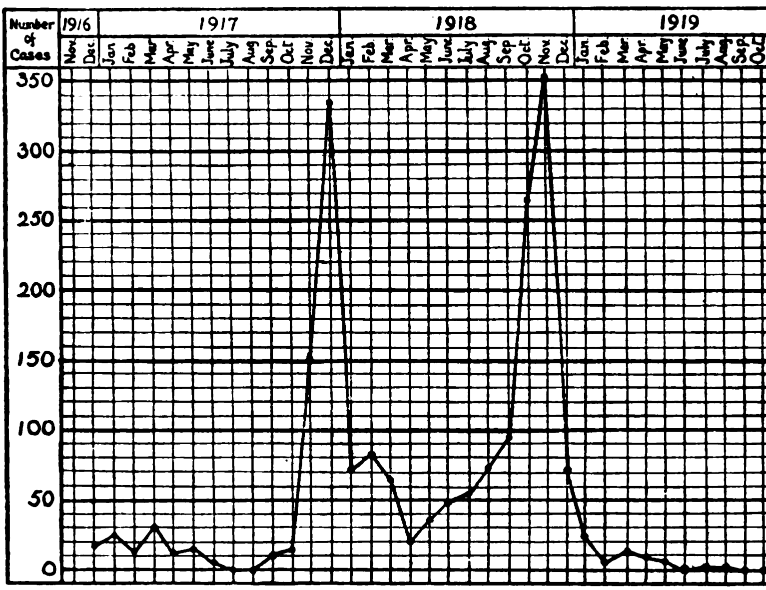

Chart I.—Incidence of smallpox among the troops in Mesopotamia.

after their inspection at Ahwaz at the end of 1916. The first case was notified there on 16th December, and the disease next appeared at the Base on 23rd December and at Amara on 30th December. On 10th February, 1917, it was reported to have broken out at Ezra's Tomb, and on 31st March at Shaikh-Saad and amongst the troops operating on the Tigris Front. On 12th May cases were reported at Baghdad, and the infection spread on 6th October to the 7th Division, on 20th October to the 15th Division, and on 27th October to the 3rd and 14th Divisions. At first the cases were few and occurred at rare intervals. There is no doubt that the authorities in Mesopotamia did not at this time realize what effect smallpox would have in an army containing many men unprotected by vaccination and revaccination, and operating in a country

where the disease was not only endemic but also very prevalent amongst the civil inhabitants. When the first case appeared in a certain unit the medical officer immediately vaccinated over 1,200 soldiers, and the authorities, while recognizing the energy of the medical officer, considered his precautions perhaps excessive. This is extremely interesting when one compares with it the great zeal of the executive officers in endeavouring to stamp out smallpox by vaccination, and the care and attention that the D.M.S. of the force and his staff had to pay to the vaccination of individuals at a later stage. The disease did not make much headway until November 1917, when, in consequence of the new regulations, many unprotected men had arrived in this country, and 152 cases were reported. In December of that year there were 337 cases. In September, October, and November of the following year there was again a marked increase in the number of cases.

It is instructive to note the causes which led to the spread of the disease. It has been stated that protection from smallpox will hold good so long as every case when it occurs is promptly recognized as a case of smallpox, and so long as each case is immediately isolated and the contacts kept under complete control by a staff of vaccinated officers and personnel. The diagnosis of smallpox is not so simple as many imagine. In the East the prodromal symptoms are clouded by those of many diseases, and until the rash appears the diagnosis is by no means certain. This was proved again and again, and Colonel Graham, A.D.M.S. (Sanitation) of the force, sums up this consideration as follows: "The prodromata are hardly distinguishable from those due to malaria and sandfly fever, and a definite diagnosis is difficult until the appearance of the rash on the third or fourth day." This refers to severe cases in unprotected men. The spread of the infection from one front to another was due to the difficulty in diagnosis, as is instanced by the first case of smallpox in an unprotected man which occurred in the 15th Indian Division. The case was undiagnosed and evacuated from an outlying station by No. 33 Motor Ambulance Convoy. The driver of the car and the attendant were both subsequently infected. By the time the disease was recognized the motor ambulance convoy had left the divisional area and was supplying the needs of another division in action. The same thing occurred in many other formations and districts.

Another feature in the diagnosis of smallpox was the difficulty experienced in the case of a very mild attack of a

man who was well protected by vaccination. The attack was so mild that only a few spots developed, the true character of which was unrecognized. The man did not even report sick and was not admitted to hospital, but all the time he acted as a definite focus of the infection and carried the infection to new areas.

It has also to be noted in this connection that in the case of Indian troops the diagnosis between chicken-pox and smallpox at certain stages of these respective diseases presented considerable difficulty. That this should be so is not surprising when one remembers that in recent years smallpox was not common in the United Kingdom, and that many medical officers who had recently qualified and were sent to Mesopotamia had never previously seen a case. The consulting physician to the Mesopotamian force was detailed by the D.M.S. to make many journeys to different parts of Mesopotamia in order to assist medical officers in diagnosing cases, and as a result of his endeavours many officers became well acquainted with the differences in these diseases.

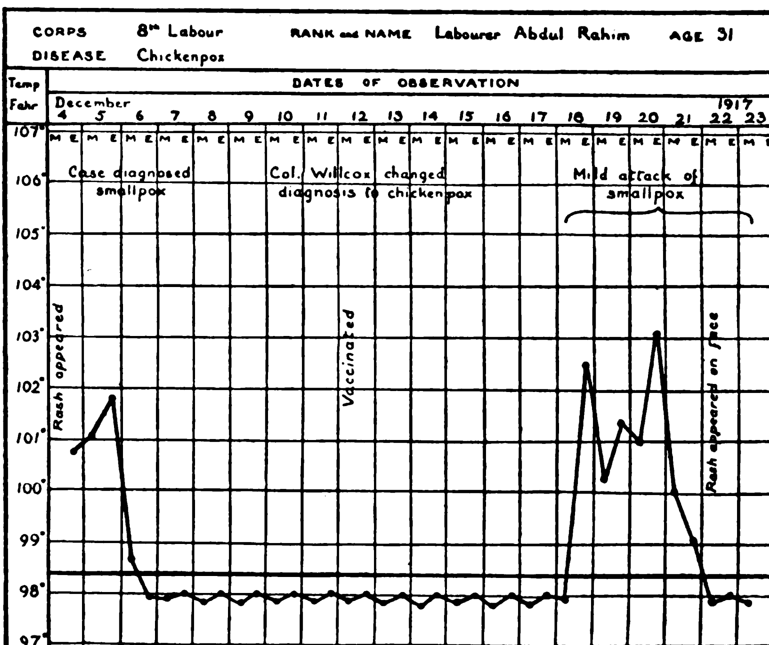

CHART II

Charts II and III are the temperature charts of two cases which were diagnosed as smallpox on 4th December, 1917, and were being treated in the smallpox ward. On 10th December, Colonel W. H. Willcox saw these cases and changed the diagnosis to chicken-pox, advising their vaccination and removal to a separate tent, where they were isolated. Two days later the patients were vaccinated, a typical mild attack of smallpox followed and the rash appeared on 22nd December. The cases had been wrongly diagnosed by experienced officers and had undoubtedly become infected while being treated in the smallpox wards.

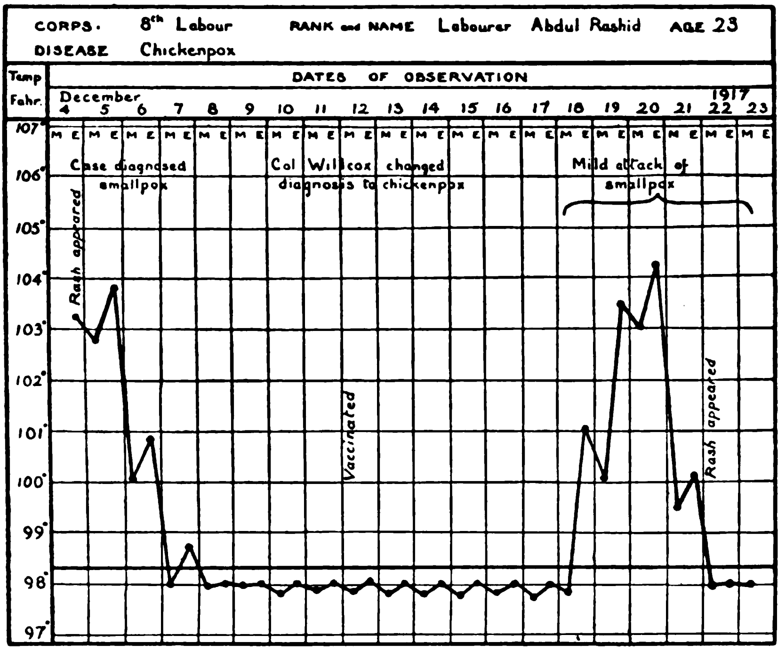

CHART III

The points he laid stress on for the diagnosis of chicken-pox were :—

(1) The superficial nature of the rash and its early appearance on the first or second day.

(2) The hands and feet are free from lesions.

(3) The patients do not feel or look ill.

(4) The short period required for the development of the papule into a vesicle and pustule and the occurrence of fresh crops of lesions so that lesions are seen in all three stages at the same time.

The War Office realized that medical officers serving with troops might not be well acquainted with smallpox as a disease, and in 1916 a Memorandum on Smallpox (Appendix D, 1) was published and distributed to all serving medical officers.

The proper isolation of smallpox cases was no less difficult than the diagnosis of the disease. Enough has been said of the difficulty of diagnosis to show that many of the cases were not actually isolated until the disease was self-evident. According to modern authorities special isolation hospitals for smallpox cases should be situated at least half a mile from the non-infected population. This was possible at bases where there was a large concentration of troops, but when troops were scattered in formations such as brigades or regiments and were encamped in perimeter camps, the selection of such a site and the extra guards and fatigues which the area commander had to arrange were not popular. At first the cases from the fighting formations were evacuated to a central isolation hospital, but later this arrangement was modified owing to the evacuation causing fresh outbreaks of the disease *en route* and field ambulances in the area where cases occurred had to arrange for their isolation and treatment. This was undoubtedly satisfactory from the medical point of veiw but it occasionally led to differences of opinion between the divisional commander in the field and Army Headquarters. In one instance a division had infectious cases isolated in four different areas. In one area alone a field ambulance was treating over 100 cases of infectious disease. This number included 40 cases of smallpox. If a division is preparing to move and commence operations, such a restriction of mobile medical units and personnel embarrasses the divisional commander. The A.D.M.S. (Sanitation) in one of his many strongly worded memoranda admitted this defect, and stated that a sharp epidemic of smallpox occurring during operations and necessitating special arrangements for evacuation might seriously interfere with the objective of the operations.

Such difficulties cannot be lightly overlooked in a force, unprotected from smallpox by vaccination, which includes a large number of men who have conscientious scruples against vaccination.

The disadvantage of not having specially equipped isolation hospitals was demonstrated in another way. The disinfection of a patient's kit and equipment, which includes such articles as tents, is very important in combating the spread of smallpox, and is difficult of performance except at an isolation hospital.

Smallpox was undoubtedly carried from the Cavalry Division to the 13th Division through the use of infected tents. The tents had not been disinfected; they were carried by motor transport convoys and used by the personnel of the 13th Division. Another example of the importance of kit disinfection was the case of an officer convalescent from wounds who was accommodated in the Red Cross Hospital at Netley. He was allowed considerable freedom and was given permission to proceed to London. While there he went over his kit, which had recently been returned from Constantinople, and took back with him several articles. A short time afterwards he developed smallpox. The case was investigated by the Directorate of Hygiene at the War Office, and the A.D.M.S. of the district, and they concluded that the infection was due to the use of these articles which had come from Constantinople and which must have been infected. Great stress has been laid on the importance of isolating and inspecting contacts as a preventive measure against smallpox, and the matter received careful consideration in Mesopotamia. Despite all the care and time which was devoted to this method of prevention, however, it was not efficient. It seems a simple matter to prepare a nominal roll of men who were in close contact* with a case of smallpox.

The distribution map (Fig. 1) shows that there were at least 305 cases at the base, 175 at Amara, 36 at Kut, and 292 in the advanced section, 157 in the 15th Division, 82 in the 13th Division, and 37 in the 14th Division. The first four stations were the important areas on the lines of communication and all reinforcements for the front line units passed through them. As the force developed, labour corps, railway personnel and inland water transport personnel formed a high percentage of the total population in these areas. The menial personnel of these departmental corps was difficult to control. They were constantly mixing with the local inhabitants in districts where smallpox was rife, and their work compelled them to move

* The term "contact" was understood in Mesopotamia to refer "to persons who have been in intimate physical contact with the sick prior to diagnosis."

from district to district. Reference to Chart I shows that the greatest number of cases occurred in September, October, November and December of 1918. During these periods the majority of cases were notified from the base and other important centres on the lines of communication. In the cases

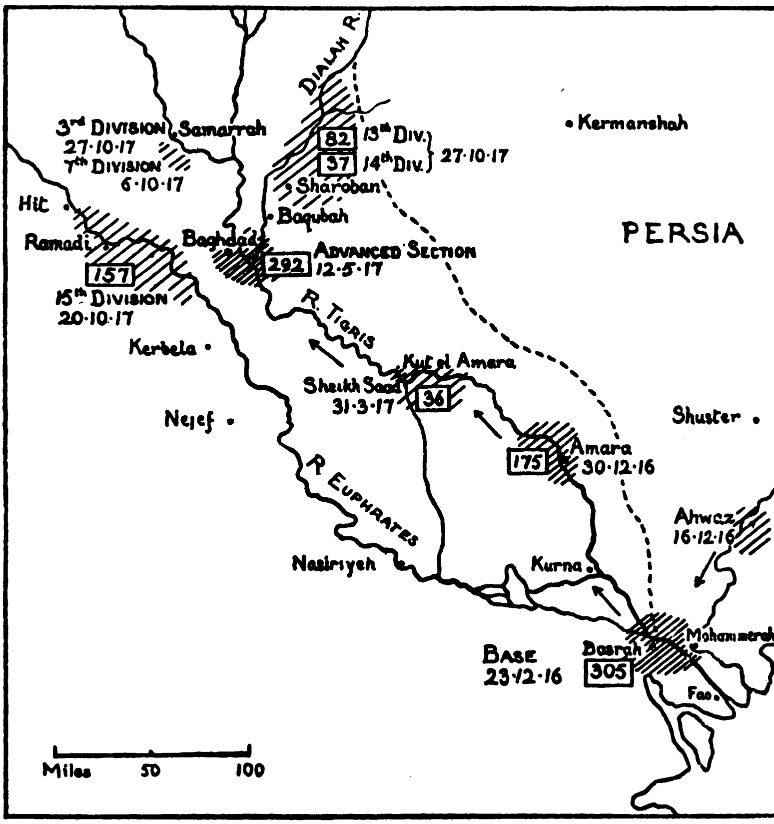

Fig. 1.—Sketch map showing the spread of smallpox among the troops in Mesopotamia. The areas affected are shaded and show the date of the first case and the number of cases.

occurring at the base alone, the percentages among the Inland water Transport personnel were 19·8 in September, 39 in October, and 18 in November. Contacts of cases in this unit could not be isolated, and the boats moving up river to the Advanced Base often carried infected personnel as the

regulations regarding contacts were not enforced, and the conveyance of ammunition, supplies and personnel was always of importance in Mesopotamia and could not be delayed.

Another interesting feature regarding contacts at the base was that, between December 1916 and April 1918, 34 cases of smallpox were taken off the ocean-going steamers which came from India to Basra. Ten cases were reported in March and seven in April 1918. The latter were removed from seven different vessels, but owing to the urgent need of shipping it was impossible to quarantine vessels which had smallpox on board. The crew were vaccinated and the military personnel on board had their kits disinfected and were vaccinated if necessary, and the ship after disinfection was allowed to proceed. The troops were sent to their respective base depôts on shore, the depôt commanders and medical officers being advised that there had been a case of smallpox.

Such instances demonstrate the difficulties of isolating contacts on the lines of communication. They were closely associated with questions of discipline and the pressing need for transport. Similar difficulties appeared at the front, and administrative medical officers, instead of having to deal with the cunning of menial orientals in evading restrictions, had to overcome a barrier of obstinacy raised by the numerous conscientious objectors and their stores of anti-vaccination literature. The number of cases amongst the A.S.C. (M.T.) convoys and motor ambulance convoys was very great. When the strength of the Army Service Corps was 2,948, there had occurred 89 cases of smallpox with 16 deaths, a percentage of 3·02 infected, and 0·54 deaths. It was an outstanding fact that the conscientious objectors to vaccination were the first to be infected. Contacts were difficult to isolate and inspect, and so the personnel of these formations aided in transferring the disease from one area to another.

During the period of demobilization after the armistice, the problem of disposal of contacts was not always easy to solve. After many years abroad men did not contemplate with equanimity the prospect of a period of quarantine when they were on their way to the United Kingdom. It was possible at certain times to isolate them for the fourteen days which the authorities thought necessary, but at other times this was impossible, and occasionally the rule had to be suspended. This was a serious problem to those who were responsible for

the prevention of the spread of the disease to the United Kingdom, as at this time smallpox was raging all over the world, and infection was being carried on board the troopships conveying troops from the Eastern theatres of war to the United Kingdom, via Italy and France. On many such vessels cases of smallpox would be reported just before the ship entered port, or a sick transfer, disembarked from a troopship, would be diagnosed smallpox on shore. It was then that the isolation of contacts was peculiarly difficult.

The results of inefficient isolation of contacts were discussed by the Inspector-General of Communications in Italy, who pointed out that a contact had arrived home and a short time afterwards his wife and children were infected with smallpox, and also his neighbours.

It was different with men not due for demobilization as they could be prevented from going to places of entertainment in smallpox areas, or from proceeding home on leave, or while on leave from entering certain restricted areas.

The methods of preventing the spread of this disease which have been described have not included any reference to vaccination or revaccination. It must not be concluded that use was not made of what to most medical officers is the most important preventive measure in dealing with an epidemic of smallpox. Complete protection by vaccination and revaccination could not be carried out owing to the Army Council Instructions which were issued in 1916. These, however, did not prevent medical officers using all the persuasive power at their command to enforce vaccination of the troops. In reviewing the question of vaccination and revaccination, many important and interesting points came to light. In the United Kingdom, Egypt, and in East Africa there were lymph vaccine institutes, and supplies of lymph for troops in these countries and in Europe were comparatively easily obtained. This facility of supply did not exist in Mesopotamia. All lymph, when smallpox was first notified, had to be obtained from India, and the question of supply raised many difficulties and necessitated not only frequent correspondence but several interviews between representatives of the Mesopotamian headquarters and the Government of India. It was a well-known fact in India that lymph lost its potency during hot weather, and exposure to a tropical sun rendered it inactive. The Medical Advisory Committee which visited Mesopotamia in the later months of 1916 first recommended a comprehensive scheme for the

transport of lymph in cold storage from India to Mesopotamia. Although the scheme was practical and appeared ideal on paper there were certain stages in the journey where the lymph could not be conveyed in cold storage to the outlying districts where troops were stationed. Consequently, although medical officers vaccinated many thousands of cases, they were disappointed with the results. The administrative medical officers of formations and areas were not long in pointing this out to the D.M.S. General Headquarters. One medical officer obtained only 0·06 per cent. successes out of over 500 cases. This was a typical occurrence and compared unfavourably with the results obtainable with potent lymph in India. In 1913 in India out of 8,981 revaccinations, 4,341, or 48·33 per cent., were successful. In addition to the lack of potency in the lymph, the actual amount required for Mesopotamia could not be supplied by India. The supply required was unquestionably a very large one, as it was desirable, not only to protect the troops by vaccination but to diminish the source of infection among the civil population by vaccinating and revaccinating the Arab children and contacts of the disease. The difficulties that beset the D.M.S. of the force will be realized when it is remembered that a vaccination campaign was being pushed as far as it was possible to do so short of actual compulsion, that the average monthly revaccinations numbered about 40,000, and that medical officers wished to vaccinate the civil population in an area extending from the Caspian Sea to Anazia in Central Asia, and that India had difficulty in supplying lymph for 15,000 doses weekly instead of the 25,000 doses required. While the shortage of lymph was acute it was decided to use the stock that was available in only those units where the disease was present and demands were urgent; for general prophylactic purposes in other units lymph would be issued whenever it became available. When the early failures had been rectified and a potent lymph became available, the D.M.S.'s efforts to secure protection by vaccination and revaccination were limited by the attitude of the troops and some unit commanders. It was therefore important that all results of vaccination should be entered in the men's Army Book 64, and that all unit commanders should prepare a vaccination state of their units, and that all men who could not produce satisfactory evidence of successful vaccination within a period of three years should be revaccinated, and if this was unsuccessful again revaccinated at intervals of one month until three successive attempts had failed. It was perhaps irksome to have to submit many times

to an operation formerly supposed to hold good for a life-time, but it was more trying to find unit commanders, instead of making the nominal roll asked for, simply calling for volunteers for revaccination. That this at times had a disastrous effect in controlling the outbreak is undoubted. The incidence of the disease amongst the inland water transport personnel, with its consequent spread throughout the force, necessitated a special communication on the subject being sent to the Inspector General of Communications by the Deputy Adjutant-General of the Force. The Director of the Inland Water Transport promised to assist in every way, but little or nothing was done.

Many of the unsuccessful cases of vaccination were attributed to improper methods, and that this was of considerable importance is shown by the fact that the War Office issued a special Memorandum on the operation of vaccination (Appendix D, 2).

Gradually the efforts of the D.M.S. succeeded, and a plentiful supply of more potent lymph was obtainable, as a vaccine institute was organized at Amara, and so provided lymph locally. A few details about the Amara Institute are interesting, as this is the first lymph vaccine institute a British force started in a theatre of war. India had been asked to supply a detailed scheme, and if possible a nucleus of personnel to start the institute. At the same time No. 83 Combined Stationary Hospital, stationed at Nasiriya, suggested a scheme for the local manufacture of lymph for the benefit of the civil inhabitants of that region. During the first fortnight in February 1919 the vaccine institute at Amara was started, and as the reserve stock of lymph in Mesopotamia had been brought up to over 500,000 doses, the weekly demand on India was reduced to 10,000 doses. The situation was further eased by the fact that the calf lymph produced by No. 83 Combined Stationary Hospital at Nasiriya had proved very successful. It was used for the civil inhabitants, giving a result of 100 per cent. successes in primary vaccinations and 40 per cent. in secondary vaccinations. By the end of February the vaccine institute at Amara had produced its first vaccine, and during the first fortnight in March it produced 10,000 doses; by the 15th April 250,000 doses were in cold storage. The tests showed 100 per cent. successes, and it was decided to cease the manufacture on 30th April, and to place the reserve in cold storage, information regarding the best method of doing so having been obtained from the Cairo Hygiene Institute, Egypt.

Fifty calves were vaccinated, 43 successfully, and these produced on an average 37 grm. of lymph, or sufficient for 13,600 doses of three insertions. The vaccine institute was handed over to the civil medical authorities of Mesopotamia on 1st July 1919. The conditions of transfer included the following stipulations: the right of the military garrison to existing reserve stock in cold storage, the right of priority of supply and at a cost no greater than that levied by the Punjab Vaccine Institute, India, which had recently been supplying the Mesopotamian force.

That the means of transit of the lymph were never absolutely perfect is shown in the following order :—

"*Smallpox Vaccine* (Calf Lymph).—Though it is looked on as potent for six weeks after date of manufacture, this period varies with method of transit and the climatic conditions. In the hot weather it may perish rapidly if exposed to great heat, whilst in the cold weather it may remain potent for three months under ordinary conditions. In cold storage at a temperature a few degrees above the freezing point (4° or 5° C. or 40° F.) it has remained potent in Egypt for over a year. The aim of all who handle it should be to arrange for its rapid transit in cold storage, preferably in thermos flasks *wherever possible.*"

In fact, the difficulties of transmitting lymph in cold storage were still present in 1920, as Colonel Graham in his report on the Health Services, Mesopotamia, in 1920, says all lymph used in Mesopotamia is made in the Amara Institute, and "the main difficulties with vaccine lymph in Irak are those of packing and transport. During the hot weather smaller quantities are sent by post in thermos flasks and the larger amounts in ice-chests, but distribution during the hot weather is reduced to a minimum, and is regarded as an emergency measure only."

All cases of smallpox were notified to the D.M.S., and the vaccination history of every case was reported in detail. While all the records are not available, there are sufficient to give the following statistics :—

In two regiments affected by smallpox the combined strength was 1,749, of which 204 men were unprotected by efficient vaccination. There were 25 cases of smallpox with 5 deaths in the unprotected and 5 cases with no deaths in the protected (Table II).

Statistics regarding the vaccination history of 1,467 cases and the case mortality are shown in Table III.

The mortality rate in 1,068 cases for the period 31st March, 1918, to 29th March, 1919, was as follows: British, 516 admissions, with 86, or 16.6 per cent., deaths; Indians, 552 admissions, with 56, or 10.1 per cent., deaths.

TABLE II.

Unit.		Unprotected.			Protected.
		No Vaccination.	Vaccination in Infancy and no subsequent successful Revaccination.	Vaccination in Infancy and Revaccination prior to 1913.	Vaccination in Infancy and successful Revaccination in 1913 or at a subsequent date.
Regiment "A" ..	Strength	12	65	77	817
	Number of cases ..	3	13	1	4
	Number of deaths..	2	3	—	—
Regiment " B " ..	Strength	7	18	25	728
	Number of cases ..	1	6	1	1
	Number of deaths..	—	—	—	—

TABLE III.

Total Cases.	Unprotected.												Protected.						No. Record.			Total.		
	No Successful Vaccination.			Vaccination in Infancy and no subsequent Successful Re-vaccination.			Vaccination in Infancy and Re-vaccination prior to 1.1.14.			Vaccination once as Adult prior to 31.12.14.			Vaccination in Infancy and Re-vaccination since 1914.			Vaccination once as Adult since 31.12.14.								
	Br.	Ind.	Tot.	Br.	Ind.	Tot.	Br.	Ind.	Tot.	Br.	Ind.	Tot.	Br.	Ind.	Tot.	Br.	Ind.	Tot.	Br.	Ind.	Tot.	Br.	Ind.	Tot.
678 cases ..	36	37	73	238	74	312	11	4	15	6	—	6	94	32	126	22	16	38	25	83	108	432	246	678
128 deaths .	25	16	41	46	12	58	—	—	—	1	—	1	11	1	12	8	3	11	2	3	5	93	35	128
233 cases ..	9	22	31	77	67	144	5	2	7	3	1	4	13	12	25	5	5	10	5	7	12	117	116	233
29 deaths .	7	4	11	11	4	15	—	—	—	—	—	—	1	—	1	1	—	1	1	—	1	21	8	29
556 cases ..	32	59	91	174	179	353	7	2	9	7	2	9	30	27	57	14	17	31	2	4	6	266	290	556
74 deaths .	18	20	38	17	11	28	—	—	—	1	1	2	2	—	2	2	—	2	1	1	2	41	33	74

In 1918 a strongly worded memorandum was forwarded from Mesopotamia by Major-General A. P. Blenkinsop, the D.M.S. of the force. The report drew attention to the situation in Mesopotamia arising from the Army Council Instructions that were issued in 1916. He asserted that these instructions greatly hampered the preventive measures in a force in the field, and that men who refused vaccination should not be tolerated in the midst of an epidemic, especially in the East, as such men were usually the first to become infected and were a menace not only to themselves but to all those in their immediate neighbourhood. So long as the disease was endemic and prevalent among the native population, units or companies might become infected at inconvenient moments. The matter was brought before the Army Council, who decided that it was out of the question to ask for legislation on the subject. The D.M.S. of the Mesopotamian force again drew attention to this matter in a letter dated 22nd February, 1918.

The Army Council Instructions of 1916 state that the regulations were to be for the duration of the war. The rules with regard to vaccination and revaccination which were in force prior to August 1914 were reinstated in October 1920.

The lessons taught by the war on the subject of smallpox stand out clearly. If compulsory vaccination is not permitted, and men unprotected from smallpox by vaccination are sent to a war area where the disease is endemic, a sharp epidemic may flare up, as happened in the French army during 1870–71. It was unfortunate that in Mesopotamia the one great essential in combating smallpox was denied to the medical services, namely compulsory vaccination. If similar conditions should occur in future campaigns, the authorities concerned should realize how great a source of weakness must be present in the event of a smallpox endemic area becoming a theatre of war. Attention should be devoted to the training of all medical officers in the diagnosis of the disease and the operation of vaccination. Further research in lymph suitable for a hot country is required. Careful plans for the proper distribution of lymph are essential, and the medical arrangements of a force will not be complete without adequate means for distributing the lymph in thermos flasks or other suitable containers. If resistance is to be offered against a severe outbreak, well-equipped isolation hospitals with modern and effective methods for disinfection will also be necessary.

CHAPTER XVII.

PREVENTION OF PLAGUE.

EPIDEMICS of plague, small or great, have not been unknown in Europe, and occasionally isolated cases are imported into the United Kingdom by ships coming from the East. The disease is associated with conditions of filth, faulty house construction, overcrowding, and insanitation, but great progress towards the gradual elimination of such conditions has been made by the existing civilized methods of sanitation and sanitary supervision. The precautions taken by port health authorities all over the world to prevent the introduction of plague into a country are well known, but the military measures adopted during the war merit a more detailed description.

Plague is still prevalent in the East, and during the war there was a widespread epidemic of the disease among the civilian population in India as well as in other eastern countries. During the period 1914 to 1917, 1,799,088 deaths from plague were recorded in India, and at Bombay during 1916 and 1917, 2,735 vessels and 920,066 passengers were inspected and 37 cases of plague discovered. As troops and labour corps were constantly being transferred from such places where plague was rife to countries which were free from it, the medical services in all theatres of war were faced with the double problem of establishing adequate measures to prevent the introduction of the disease into the various expeditionary forces, and of coping effectively with it, should an outbreak occur. In Mesopotamia only did plague make any headway, and it is safe to say that of the diseases affecting the troops in this theatre of war it was the one least heard about, though it caused the D.M.S. of the force more anxiety than all the others.

On the Western front in February 1916 it was rumoured that the Germans might use plague as an offensive weapon against the allied armies, but this was considered highly improbable. In view of the rumour, however, the A.D.M.S. (Sanitation), in France advised the Director-General that all sick or dead rats, whose condition was not due to the measures taken for their destruction, should be sent to a laboratory for

examination. The French at the time were making a determined attack against rats inhabiting the front line, and their methods were used by the British co-operating with them.

The French employed principally poison baits, dogs, and rat-catchers. The chief ingredients in the poison baits were the preparations of squills. A school for the training of dogs for ratting purposes was instituted and stress was laid on the following points: selection of a suitable breed of dog, for example, fox terriers; training the dogs to catch and kill rats quickly; using the dogs intelligently, that is, not spoiling them by making them regimental pets. It was found that dogs suitably trained could catch from 100 to 150 rats per day, and that although unsuitable for work in the trenches they could be used with advantage in clearing rats from barns, billets, and farmyards.

The rat-catchers were paid at the rate of ½d. per rat, and in one fortnight they disposed of 8,000 rats. The British armies in France found it was no advantage to organize energetic methods for local areas, as if one area was cleared of rats it was quickly re-inhabited by other rats from a neighbouring area. Army areas were accordingly divided up into sections, and two men, usually game-keepers, farmers or poultry men in private life, were selected to organize and co-ordinate the methods of destruction of rats. These methods included the setting of poison baits, the protection of food supplies by using vermin-proof stores, the erection of rat-proof fences by burying wire netting 18 in. below the ground and fixing on the top of the netting a piece of tin sloping down on the outside, and the protection of all the natural enemies of the rat. It was found that Liverpool virus, other patent poisons, and the use of gas such as was employed on board ship, were unsuitable for the trenches. The anti-rat measures found best suited for France were circulated in the following memorandum on 27th January, 1917:—

Measures proposed for the Destruction of Rats.

I.—*Anti-rat Measures.*

Measures taken for the destruction of rats should be carried out simultaneously over a wide area, and reliance should not be placed on any one procedure. Extermination is impossible as rats can readily migrate from the German lines, and probably will do so if the density of the rat population in our area diminishes. The most that can be hoped from measures against rats is some reduction in their numbers.

II.—*Traps.*

Mechanical traps of various designs can readily be improvised. The same type of trap should not be used in one locality for more than two or three nights.

In addition to traps which kill rats at once, boxes, tubs and pits with sides sloping outwards to the floor are effective. Rats which have entered are unable to escape and can be killed at leisure. Any bait which may be used should vary in character and should frequently be changed.

The services of any men having special knowledge in rat-catching should be utilized.

III.—*Poisons.*

To guard against accidental poisoning it is desirable that notice should be given to all concerned when phosphorus paste, extract of squills, or any other rat poison is laid down. The receptacles containing the poison should be labelled and bait unconsumed by rats destroyed.

(*a*) *Phosphorus Pastes.*—These preparations are effective when consumed by rats. Very quickly, however, rats learn to avoid this poison and its use should be alternate with other poisons.

Phosphorus may be used in the form of a vermin-killer or rat paste by spreading on bread, cheese or meat. The following method of placing the bait is to be recommended :

Two wooden boxes are used, one considerably larger than the other and each having two or more holes in the sides large enough to admit rats. The poisoned bait should be placed in the bottom and near the middle of the smaller box and the larger box should then be inverted over the other. The boxes should be painted a distinctive colour.

(*b*) *Scilline* (*Liquid Extract of Squills*).—Bait containing liquid extract of squills has been found effective in killing rats. Detailed instructions for its use have already been issued.

(*c*) *Calcium Carbide.*—Fragments of calcium carbide dropped into rat burrows will drive out the occupants.

(*d*) *Bacterial Virus.*—These are dangerous to man and should not be used. They are, moreover, not efficient rat poisons, as only a proportion of the rats partaking of them succumb.

IV.—*Natural Enemies.*

Cats, dogs, and ferrets might be used and other natural enemies such as owls, kestrels, sparrow hawks, herons, rooks, gulls, weasels, and stoats should be protected.

V.—*Food.*

Whenever circumstances admit, all food should be protected by means of wire netting or kept in wire gauze safes. Where food is permanently stored a rat-proof fence should be, if possible, provided and all rats inside this exterminated. The fence can be made of wire netting buried 18 in. under the ground, and along the top a piece of tin is fastened sloping downwards towards the exterior. All food refuse should be carefully collected and removed.

At a later date a few cases of plague were reported on board transports at Marseilles, and the administrative medical officer of that area pointed out the danger likely to accrue if infected cases were landed in a town such as Marseilles, which had a large rat population. Measures were taken to prevent any infected cases being landed.

In January 1918 the D.M.S. of the Fifth Army reported that the mobile laboratory in his area had examined some material dropped by an enemy balloon, and that bacilli resembling the *Bacillus pestis* had been isolated. Increased attention was therefore paid to the destruction of rats and the notification of any disease found amongst captured rats.

In Italy, cases of plague occurring either amongst the civilian population or the personnel of transports and ships were reported at several of the different ports, whereupon correspondence passed between the Italian and British medical authorities at these ports. It was decided, however, that the measures already in vogue were sufficient.

In Salonika 20 cases of plague were reported amongst the civilian population in 1916. Medical officers from the different allied forces held a conference and co-operative measures were drafted and approved. The naval and army embarkation medical officers carried out these measures on behalf of the British.

In East Africa several small outbreaks of plague were reported, the most extensive being at Nairobi. With the exception of an outbreak on the transport "Barjorah" in August 1917, when 32 cases were reported, there were few cases amongst the military personnel. This outbreak was traced to Nairobi and had one good result in that it assisted the medical authorities to obtain an island outside the harbour at Dar-es-Salaam as a quarantine station. At Nairobi, between 12th May and 25th August, 1917, there were 8 cases amongst the military personnel and 51 cases notified amongst civilians, the type of plague being bubonic.

The outbreak also served a useful purpose in drawing attention to the fact that there were no facilities for de-ratization and disinfection on a large scale of ships at Dar-es-Salaam, a town frequently attacked by plague in the past and at all times liable to infection. After this epidemic, orders for the protection of the forces were drawn up.

While the spread of infection from the civilian population to British armies in the field was the problem which chiefly concerned the military authorities, it is interesting to note that at Karonga, in Nyasaland, plague was supposed to have been introduced by the military operations. In the villages in this district towards the end of 1916 there were 33 cases with 19 deaths, and although it was known that prior to the war foci of the disease existed in the country and an epidemic occurred in 1912, Karonga had been more or less isolated since the military advance commenced in June 1916. The outbreak was investigated, and the conclusion arrived at was that there was no reason for suspecting that infected rats and fleas might have been carried in cargo from India, but that the source of the disease was German East Africa, whence it was probably brought by carriers during the operations of 1916.

In May 1917 there was an outbreak in the Luangwa valley, and 96 cases were reported with 93 deaths. The disease had been imported from Karonga, Nyasaland. Subsequently in the same region there were other 59 cases with 56 deaths. The preventive measures adopted were limitation of native movements, burning of infected villages, and an anti-rat campaign.

In connection with the anti-rat campaign in the Karonga area, some idea of the immensity of the campaign may be gathered from the numbers of rats captured in one week. For instance, from 7th to 13th October, 1917, over 100,000 rats were destroyed, and in the following week 76,000. The rats were brought to definite rat depôts and prices paid according to the numbers of rats received. The natives and staff employed at these depôts had all been repeatedly warned not to touch the rats with their hands. The tails were cut off and the numbers entered in a ledger, also on cards kept by the rat-catchers, and accounts were settled at the end of each month. The bodies of the rats were incinerated.

In Egypt there were 2,888 cases with 1,458 deaths during the period 1914 to 1917. In 1917, from April to June, several cases of plague were detected amongst the British troops stationed along the canal. The port medical authorities at Suez and Port Said were always on the alert to prevent the infection spreading to the east or west.

To appreciate fully the difficulties in Mesopotamia it is essential to mention a few outstanding points with regard to plague.

The disease affects rats and is carried to the human being principally by fleas which have fed on an infected rat. Both the brown rat (*Rattus norvegicus*) and the black rat (*Rattus rattus*) are liable to infection. The former is known as the common rat, water-rat, barn-rat, or sewer-rat; the latter is more commonly called the ship-rat or house-rat. The brown rat is the more prolific and produces several litters in the year, numbering on an average from six to nine young but sometimes as many as twenty-two. The chief breeding season extends from February to the early autumn. It has been said that one pair of rats within nine months will give rise to a progeny of 880, and if these are supplied with food and left unchecked the total number of rats at the end of the year would be 35,000.

In the east, plague usually appears first in the *Rattus norvegicus*, then in the *Rattus rattus*, and subsequently in man.

The rat-flea of the tropics is the *Xenopsylla cheopis*, but the *Ceratophilus fasciatus* was also found in Ashar to the extent of 8 per cent. The flea feeds on the infected rat and accumulates a large mass of *Bacillus pestis* in its alimentary canal. This mass is sufficient to cause a partial obstruction, and when the rat-flea attacks the human being there is regurgitation from the flea's stomach with consequent infection of the victim. Infection may also occur through the fæcal deposit of the flea being rubbed into the sore.

The prevalence of fleas is intimately associated with the season of the year. It has been stated that the most favourable time for their multiplication and activity is when the temperature is between 10° to 30° C. (50° to 86° F.). When the temperature is over 30° C., or 86° F., and the atmosphere is dry, conditions are unfavourable for the flea. The flea infestation increased as the cold weather approached. In some areas, notably at No. 33 British General Hospital, flea counts numbering hundreds per rat were noted. The mean maximum temperature when the plague epidemic in Mesopotamia was at its worst is shown on the incidence chart. The average life of the flea apart from its host is about ten days, while in tropical temperatures this insect can harbour the *Bacillus pestis*, when feeding on blood, for a period of forty-five days, an important point in the spread of infection.

Rats are known to quit villages in anticipation of an epidemic of plague, and it is also known that a chronic form of the disease may exist in a rat for a long period without actually killing its victim. This accounts for isolated cases appearing at rare intervals in certain areas. Other animals may become infected with plague, the most common being mice, sheep, deer, pigs, and dogs.

Mesopotamia had an unenviable reputation for plague; it had been frequently attacked, and at one time 100,000 persons perished in Basra alone, while no fewer than 60,000 out of a total population of 150,000 died of the disease in Baghdad. The conditions of the towns and villages were absolutely appalling to one with a European idea of sanitation. It has been truly said that plague follows trade routes. The base and large centres on the lines of communication had to be situated amidst or near such insanitary surroundings. The base at Basra, for example, had a military population of 120,000 at the beginning of 1918, and the camp extended along the river front and back into the desert areas of Magill and Makina. Ashar town was partly occupied and was in the vicinity of the

camps. Communication with the front until 1917 was mainly by river, and transport areas had to be constructed along the river banks; all stores had to be carried by ships—ideal conditions for the spread of plague.

It is common knowledge that rats attack stores and forage built in stacks, and also that they will go a considerable way to do so. In one area alone it was proved that the rats lived in a neighbouring palm grove while they fed on the supply stores. Recent research has demonstrated that the rat-flea can be transferred through grain and in grain sacks, and this accounted for cases of plague developing on ships free from rats but carrying grain from Basra to Qurna, Amara, and Baghdad.

In March 1916 suspicious cases resembling plague were reported in the hospital transport, "Nile," then anchored in Koweit Bay. An officer with experience of plague was sent down-stream to investigate these cases, and arrangements were made for transhipping the troops to the H.T. "Vita" and for detaining the H.T. "Nile" in quarantine.

Early in July epizootic plague amongst rats made its appearance in the Indian base depôt at Basra. About the middle of July human plague was reported in an Indian hospital. For the next two years plague, so far as the British forces were concerned, was confined to Basra, Qurna and Nasiriya. At Basra cases of plague were taken off ocean-going transports that had arrived from Bombay. The first cases at Qurna and Nasiriya had been infected in Basra; the former was a transfer from a river steamer, the latter from the railway.

It is interesting to note the method of spread of the disease. A typical example is taken from the records of the outbreak of plague at Qurna. On 14th May, 1917, an infected rat was found at the post office, and on 29th May nine mummified and decomposed rats were discovered at the house of the Assistant Political Officer, next door to the post office. On the same day a sepoy of the 44th Merwaras, who was on guard duty at the house of the Assistant Political Officer, and an Arab woman in the adjoining house contracted plague. On 1st June the husband of the latter was infected, and another infected rat was found 300 yards from the post office.

In the summer of 1918 there was a severe outbreak amongst the civilian inhabitants at Amara, and the infection spread to the military population of that town, 16 cases being reported. In the second week of March 1919 a severe epidemic broke out amongst the civil population of Baghdad and its environs.

Cases admitted to hospital from the Mesopotamian Expeditionary Force from July 1916 to 31st October, 1919, numbered 411. Of these, only 24 were amongst British personnel; the rest occurred mainly amongst the subordinate personnel of such corps as the Inland Water Transport, Railway Corps, and Labour Corps. From Basra alone 318 cases were admitted, from Qurna 8, from Amara 20, from Kut 1, from Baghdad 25, from Nasiriya 5, from the Euphrates Section 2, and 3 from the 17th Division. While it is impossible to give the actual numbers of civilian cases admitted from the same districts, there are records of 498 cases being admitted from Basra, 29 from Qurna, 323 from Amara, 42 from Kut, 882 from Baghdad, and 154 from Kadhimain, a suburb of Baghdad. The distribution of military and civil cases is shown on the sketch map. (Fig. 1.)

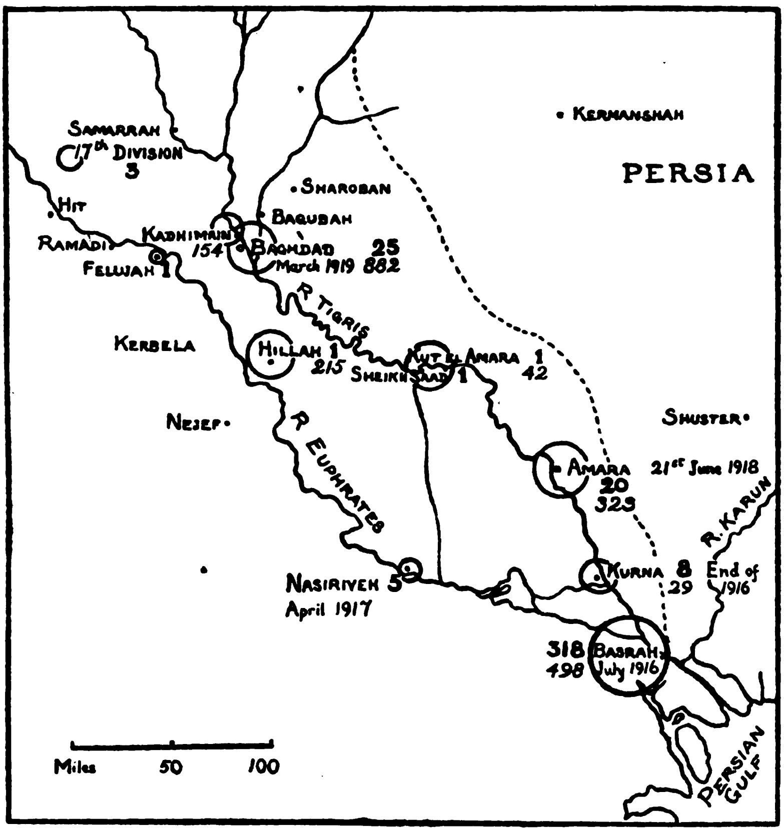

Fig. 1.—Sketch map showing the distribution of plague in Mesopotamia. Military cases are shown in black figures; civil cases in italics.

The worst epidemic occurred during the first seven months of 1919. Chart I shows the incidence amongst the military and civil populations at that time, the mean maximum temperature, and also the death-rate amongst the military population. The distribution of these cases and the numbers of cases reported from the main centres on the lines of communication explain why the disease caused the Director of Medical Services considerable anxiety, as one of the recognized methods of protecting individuals from the disease is by evacuating infected areas. To consider the evacuation of organized lines of communication centres is no light matter, especially in a force operating three to four hundred miles from its sea base. Schemes for the evacuation of Qurna, Amara, and the Advanced Section at Baghdad were prepared and kept in readiness in case of emergency.

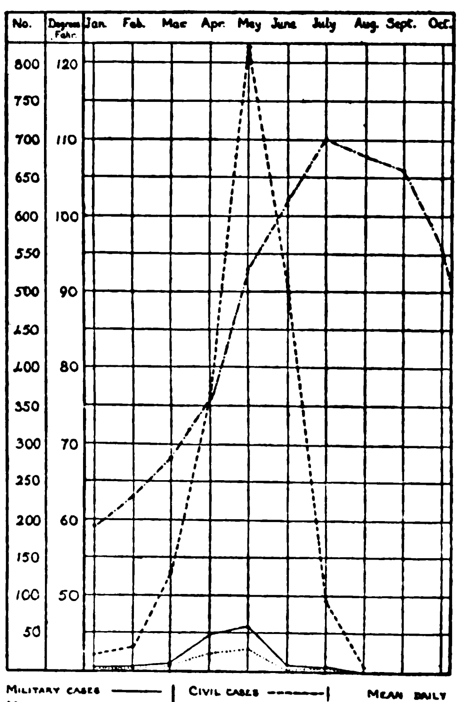

Chart I.

The first preventive measures put into operation by the D.M.S. of the force were the appointment of a special plague officer at Basra and the circulation of a printed pamphlet on

the disease to all medical officers in November 1916. This publication dealt with the origin of infection of the first cases reported in an uninfected area; an outline of the action to be taken; the protection of individuals; the protection of the community; the general principles of rat destruction; poison baits; flea destruction, and the *post-mortem* signs of plague in a rat. Later, a plague officer was appointed at Baghdad, and an assistant plague officer on the lines of communication. These officers were given special laboratories, and advised the D.M.S. regarding the preventive measures required. The officers appointed belonged to the Indian Medical Service and all had devoted special study to the subject in India. Every case of plague was at once notified by telegram. This was essential owing to the possibility of having to evacuate certain centres very quickly.

The preventive measures instituted can be conveniently divided into two groups: those for the protection of the community, and those for the protection of the individual. In the former case rat destruction and flea destruction are pre-eminent. In the Basra base 139 cases were reported between January and July 1918, and of these 114 were admitted from various hutted camps: 39 cases from the Inland Water Transport dockyard; 15 cases from the Inland Water Transport camp, North Magill; 8 cases from the Base Transport Depôt; 7 cases from No. 33 British General Hospital; 6 cases from the 30th Persian Labour Corps camp; 5 cases from the port traffic camp; while 34 cases were admitted from 17 different hutted camps. The cases were chiefly amongst Chinese and menial Indian and Persian labour personnel, personnel that was difficult to control and had little regard for the sanitary principles of camp life.

The huts in the Inland Water Transport dockyard were fitted with sleeping benches 3 ft. from the ground. The space between the benches and floors was used for storing kits, rations and other articles, and formed a "happy hunting ground" for the rat. In No. 33 British General Hospital huts were constructed with boarded floors raised 4 in. above the ground, and this also was a favourite resort. In other camps, huts were constructed with double roofs, and here again the interspace served as a resting and nesting place for rats. In the different types of huts 361 rats were captured, and as 64 were found to be infected with plague, it was decided to do away with sleeping boards and raised floors. It was found that cement was the best material for flooring huts, or where this was not available 6 in. of earth were broken up and mixed with ashes and heavy

oil and then rammed down hard. Stricter attention was also paid to the details of hut cleanliness. Inspections were frequent, and ultimately the menial personnel were forced to keep their huts tidy and clean. Efforts were also made to protect supply, unit and mess ration stores from attacks by rats.

Extensive schemes for rat destruction were put into operation in all infected areas whenever a plague-infected rat was discovered, and the area for two or three hundred yards around the nidus of infection was trapped and baited well. Special personnel in the different units were trained for this purpose. Some idea of the magnitude of this task will be gathered from the following figures. Between 1st and 12th October, 1918, in Baghdad, 1,922 traps were set in 1,206 houses ; in the same area between 1st and 15th March, 1919, 5,548 traps and 11,900 baits were set.

It was found that the best composition for 1,000 baits was barium carbonate 6 oz., common salt ½ oz., wheat flour 4 oz., bajri flour 12 oz., ghi (clarified native butter) 4 oz. The salt, poison and flour were thoroughly mixed together and then made into a stiff paste with the ghi, and the mass was divided into 1,000 baits each the size of a hazel nut. When barium carbonate and bajri flour were not available, ½ oz. of arsenic and 12 oz. of wheat flour were substituted. Fifteen to twenty baits were used for a room the size of the European pattern tent, and five to ten for subsequent baitings. In addition, gardens and compounds where rats were likely to be found were also baited. The baitings were continued in an infected area at intervals of about a week until a full month had elapsed since the last case or plague rat had been found in the area. During the off-season, if plague-infected rats were discovered in any town, the baiting was continued throughout the whole period. Traps were found suitable for keeping the rat population reduced when once this had been effected by the use of rat poison. It was found that traps operated by a light counterpoised weight were more suitable than those worked by a spring.

While these methods were employed on shore, a scheme was devised for destroying the rats in ships and barges by using Clayton disinfecting machines. These were installed in a small vessel, and disinfecting personnel detailed by No. 29 Sanitary Section were placed on board to supervise the plant and the disinfection of the ships. This was established at Basra, and the original proposal put forward was for three river steamers and barges to be disinfected daily. A total of 353 river steamers had to be disinfected, which at the rate of three daily would have

taken over three months to accomplish. But this could not be carried out, and in one month only 52 steamers were disinfected. Later on similar arrangements were made at the Advanced Section Baghdad, and a complete system of inspecting boats by port medical officers at Qurna, Amara, Kut, and Hinaidi, the port of Baghdad, was instituted on 8th August, 1918. While this was satisfactory, it raised difficulties, as when a case of plague was discovered on board ship and the vessel placed in quarantine the precautions were apt to be relaxed because they happened to cause temporary transport difficulties. The medical authorities never willingly gave in to any relaxation of the quarantine rules because they felt that the danger of plague paralysing the efficiency of the whole force was too grave to permit of any risks being taken.

In May 1919 the Clayton barge at the base undertook the "claytonizing" of an overseas liner, the S.S. "Dumra," which was plague-infected. The operation lasted ten hours; half a ton of sulphur was burned and 76 dead rats were retrieved at the end of the operation.

Precautions were taken at each port to prevent rats leaving or boarding ships.

All rats that had been trapped were examined in the plague laboratories, and in many cases a flea count was made. To give some idea of this work it is enough to record a few figures. In Basra, between 1st September, 1916, and 16th January, 1917, over 1,100 rats were examined, of which 89 were found to be suffering from plague. In Baghdad, between 3rd January and 14th February, 1919, 1,342 rats were examined and 37 were found to be suffering from plague. As has been stated, the fleas on each rat were counted and the workers in these laboratories were able to reproduce a chart showing the flea prevalence in Mesopotamia. At one time the flea rate per rat rose from 4·3 to hundreds per rat, a high rate, and was consequently very apt to favour the spread of the disease.

While the British quarantine rules were efficient as regards the discovery and notification of cases of plague on board British ships, the question of native craft was always difficult, as the Arabs were adepts at subterfuge and never relaxed their efforts to escape inspection. Many cases were brought to light of plague-infected civilians being placed on board Arab sailing craft and covered up with blankets and other material.

Flea destruction was carried out by the disinfection of kits and quarters. It was found that during the hot weather,

when the temperature was over 120° F., infected kit or merchandise could be sterilized by exposure to the mid-day sun for one hour. Disinfectors were also useful, and floors and areas were painted over with "pesterine," which was made of kerosine (20 parts), soft soap (1 part) and water (5 parts). The soap was dissolved in the water and the oil gradually stirred into the hot mixture.

Inoculation is the chief measure of protection for individuals. Medical officers who had served in India were familiar with the good results obtained by the inoculation of personnel in a plague-infected area. In 1911 the Bombay Bacteriological Laboratory published the following results: Amongst the inoculated, 8 per 1,000 became infected, while amongst the uninoculated the number was 34 per 1,000; the case mortality in the former class was 39·5 per 1,000, compared with 78 per 1,000 in the latter. Efforts were therefore made to protect by inoculation the military personnel in infected areas.

In 91 military cases occurring up to 7th June, 1919, at Basra, 30 were inoculated and 61 had not been inoculated. The case mortality in the former was 20 per cent. and in the latter 70·5 per cent. During the first half of 1918, when plague was still confined to Basra, Qurna, and Amara, 36,810 military personnel were inoculated.

When plague was at its worst in 1919 inoculation centres were opened for the civilians in all the large towns. The great difficulty was to induce the women to come forward to be inoculated. For this reason nurses were trained to carry out the operation amongst them. Half the population of Baghdad, namely, 84,408 people, were protected by inoculation, and including the outer districts a total of well over 100,000 inoculations was achieved. In attempting to inoculate the civil inhabitants of the towns in Mesopotamia, the success of the measures depended to a great extent on the manner in which the political officer presented the idea to the people. In Baghdad and in Qurna the political officer was sympathetic, and in the former case 50 per cent. and in the latter 75 per cent. of the population were protected by inoculation. In Kadhimain, however, the political officer was not so sympathetic, and despite the fact that 154 cases of plague were reported within a few days, only 250 Arab women and men presented themselves for inoculation and the inoculation centre had to be closed down. The mortality amongst the cases in the civil population varied from 68·2 per cent. to 70·9 per cent. In one series of 380 civil cases only 28 were amongst the inoculated.

The question of inoculating the civil population on a large scale raised a considerable demand for anti-plague vaccine from India. In November 1916 the officer commanding the Base Medical Store Depôt was authorized to stock large quantities of plague prophylactic, and subsequently all medical store depôts were urged to build up a large reserve of anti-plague vaccine for civil and military purposes. India readily supplied all the demands made.

The evacuation of infected areas was always uppermost in the mind of the D.M.S. and his advisers. As has been previously stated, the question of evacuating Qurna, Amara, and the Advanced Section had been considered. Fortunately this was never necessary owing to the stringent measures recommended by the D.M.S. and the energetic manner in which they were carried out by the medical officers of the force. Evacuation of localized areas, such as moving military personnel from infected houses, the clearing out of a small bazaar or small village yard or the surroundings of a store depôt, was a fairly frequent occurrence, and such measures never gave rise to serious trouble.

Protection from fleas and the disinfection of clothing were routine duties of the disinfecting stations and medical units. The fact that infected fleas may be carried in grain made it necessary to restrict the movements of grain belonging to the civil population from one area to another. Grain which had to be moved for military purposes was loaded at the base and unloaded at Baghdad at special wharves. It was also necessary to restrict the movements of civil personnel. These preventive measures gave rise to considerable difficulty, as the Arabs were unwilling to submit to these restrictions. Here again much depended on the efforts of the political officer, who acted as the liaison officer between the civil authorities and the medical authorities of the force.

It is of interest to note that practically all the cases were bubonic in type, though one case of pnuemonic plague occurred in an Indian sepoy. One British soldier developed symptoms resembling those associated with acute inflammation of an abdominal organ. He was operated on and the condition was diagnosed hæmorrhagic pancreatitis owing to the matted and inflamed state of the abdominal lymph glands. On examination in the Central Laboratory, however, these were found to be infected with the *Bacillus pestis* and the case was diagnosed primary abdominal plague, a type of plague rarely seen even by those who have devoted years of study to this disease. In 92 military cases about which statistics are available, the primary

seat of the disease was as follows :—inguinal bubo 52, axillary bubo 23, cervical bubo 13, miscellaneous 4. Of the miscellaneous cases two had epitrochlear buboes, while two had no buboes but flea-bite ulcers, and the discharge from these contained *B. pestis*. Multiple buboes were met with on three occasions.

It was noticed in four cases inoculated either during the incubation period of the disease or during fervescence that such cases died from profound septicæmia more rapidly than the non-inoculated cases.

In the case of buboes about the region of the neck it was noticed that the throat became congested and the patients expectorated blood-stained saliva from which pure cultures of the *B. pestis* were grown.

It is not necessary to describe further the type of case or treatment that was carried out in the infectious hospitals. As the force developed these institutions were equipped with all modern appliances. The consulting physicians of the forces visited them regularly, and all details concerning the precautions that should be taken by attendants on plague cases were efficiently carried out. These included the wearing of rubber gloves, overalls, masks and goggles. The partaking of food or drink in plague wards by the attendants was prohibited. Cases were retained in hospital until completely convalescent, and contacts were kept in quarantine for five clear days.

BIBLIOGRAPHY.

Fremantle	Health Work in Mesopotamia	Contemporary Review, 1919, No. 648, p. 654.
Low, Bruce.. ..	The Progress and Diffusion of Plague, Cholera and Yellow Fever throughout the World, 1914–1917.	Reports on Public Health & Medical Subjects (Ministry of Health), Lond., 1920, No. 3.
Taylor	Rat and Plague Conditions in Hutted Camps.	Ind. Jl. Med. Res. (Special Indian Medical Science Number), 1919, p. 173.

APPENDICES

APPENDIX A.

Orders for Prevention of Disease being introduced by Prisoners of War.

PRECAUTIONARY MEASURES AGAINST THE INTRODUCTION OF TYPHUS FEVER.

(Army Routine Order on recommendation of D.G.M.S., February 1915.)

"In view of the report that typhus is present amongst certain German and Austrian armies, and considering the movements of German troops between the various fronts, the following main preventive measures are recommended to be adopted, as circumstances permit :—

(1) Medical inspection of German prisoners should be carried out as soon as possible after their capture, and daily inspection continued until they are evacuated.

Should a suspicious case be observed, the patient, the whole batch of contact prisoners, and their guards should be segregated at once.

(2) Prompt and thorough disinfection of the clothing and persons of all German prisoners should be instigated at the earliest opportunity.

(3) Sanitary measures should be carried out in all buildings, billets, or trenches which may be taken from or abandoned by the enemy. Straw, bedding, clothing, and anything likely to harbour lice should be burnt.

(4) The interior walls of houses, wooden floors, partitions, and furniture are to be well saturated with cresol. Dangerous ground areas should be sterilized by firing with straw, aided if necessary by paraffin.

Any other measures dealing with the destruction of lice, which are found practicable, are to be taken."

"In the case of wounded German prisoners in hospital, precautions should be taken against the possible spread from them of typhus fever. The precautions to be adopted include :—

(1) Segregation for a period of fourteen days.
(2) Prompt and thorough disinfection of clothing and person to destroy lice.
(3) Daily medical inspection."

(Sd.)....................
Surgeon-General,
D.M.S., L. of C.

H.Q., I.G.C.,
17.4.15.

CHOLERA.

"To guard against the possibility of the importation of cholera by Bulgarian prisoners or deserters, I propose that the following precautions be taken :—

(1) From the day they are taken, for seven days they should be seen daily by a medical officer to ascertain if they are suffering from any indications of the early symptoms of cholera.

(2) At divisional headquarters and at any other place where they are detained for a day or more they should be kept in a separate enclosure with latrine accommodation which must not be used by any other person. These latrines must be under constant sanitary supervision to prevent the spread of infection by flies, by contamination of water supplies and by fouling of the ground.

(3) They should be detained as short a time as possible at the front.

(4) Immediately before being despatched to the base they should be inspected by a medical officer.

(5) On arrival at the base, during a period to complete seven days from their arrival in our line, they should be kept in a separate enclosure with separate latrines, and not allowed to mix with other prisoners or to be away from the camp with working parties, etc., except in so far as is necessary for their being interrogated.

During this period they will continue to be seen daily by a medical officer.

The strictest possible sanitary supervision will be exercised over this camp.

(6) As soon as possible after their arrival at the base, unless this can be done before, all their clothing and kit will be disinfected.

(7) Should a case of cholera occur among them it will be dealt with as directed in this office, No. 1006 of 23.5.16, issued to all D.Ds.M.S."

(Sd.)............Surgeon-General,
Director of Medical Services,
Salonika Army.

A.H.Q., Salonika,
1st August, 1916.

APPENDIX B.

Cerebro-spinal Fever.

1.—*Specimen of Cerebro-spinal Fever Card for recording each Case.*

Command.

Name of { Patient ....Rank..............
Regiment ....Regimental No................
Station.....................................Age.......... }

Address at time of onset............................Service..........

How housed...

Any overcrowding...

Date of :—
Notification to War Office............; Onset of illness............;

Admission to hospital................

Name of Hospital...

Whether any source of Infection traced :—

Name of { Bacteriologist...
Record Keeper...
Laboratory... }

Result—Date of { Discharge.................. Sequelæ................
Death .... }

Lumbar Puncture made..	Date													
	Amount of Fluid withdrawn.													

Result of Bacteriological Examination of .. (a) Cerebro-spinal Fluid (b) Naso-pharynx ......
(c) Blood............ (d) Urine..............

Type of Meningococcus present..

Clinical Condition of Patient on admission :—

Serum given	Dates..								
	Amount								
	Brand of Serum and Mark Number								

Effect of Serum on Clinical Condition (a) General..
(b) Local..

Date of Swabbing Contacts................

Number of Contacts—Negative.......... Positive........ Total........

Date of subsequent Examination of Positive Contacts.	Date				
	No. Positive ..				
	No. Negative ..				

Date of Report............Signed by................ Rank............

Record Keeper..................

2.—*Specimen Letter sent to each Command indicating the lines on which Reports should be written.*

It is desired that each of the bacteriologists and record keepers who have been engaged in investigating either cerebro-spinal fever cases or contacts since 1st July 1917 should make a report on the work done in their districts during the period 1st July, 1917, to 30th June, 1918.

A.—A list of the cerebro-spinal fever cases dealt with should be furnished with the report, showing the following particulars regarding each case :—

(1) Name.
(2) Rank.
(3) Regimental number.
(4) Unit.
(5) Age.
(6) Length of service.
(7) Date of onset.
(8) Station.
(9) Date of joining station.

(10) Station from which joined.
(11) Movements in four weeks prior to onset of the disease ; if the patient belongs to a British overseas unit or is a member of the Army of the United States, the date of arrival in the United Kingdom and the name of the transport on which the patient travelled to Europe should be given. It should be stated whether any cases of cerebro-spinal fever occurred during the voyage. The date of onset of such cases should be given.
(12) Source of infection, or possible exposure to infection, or association with previous case or suspected case of the disease.
(13) Result (with date)—death or
recovery (partial or complete, and whether sent to Hitchin C.S.F. Convalescent Hospital).
(14) Type of meningococcus found in :—
(1) Cerebro-spinal fluid.
(2) Naso-pharynx.
(15) Remarks.

Similar information should be given of each case which has occurred among the female nursing staff, members of the W.A.A.C., civilian workers in barracks and camps, Portuguese labourers, and prisoners of war.

B.—Information is particularly desired on the following points :—

Cases of cerebro-spinal fever.
(*a*) *Mode of spread of the disease.*
(*b*) *General predisposing conditions.*

Effect of : (1) Season.
(2) Meteorological conditions.
(3) Overcrowding or other unhygienic conditions.
(4) Fatigue or exposure.
(5) Age.
(6) Length of service.
(7) Vaccination or inoculation.
(8) Catarrhal condition (*e.g.*, colds, "influenza," mumps, measles, etc.).
(9) Abnormalities of the naso-pharyngeal passages.
(10) Locality in camp, barrack, billet specially affected.
(11) Other factors which may have come to notice, such as the effect of arrival or reinforcements from overseas, railway journeys, leave, change of station, special occupations, etc.

C.—Incubation period.
Has there been any opportunity of making observations on this point ?

D.—(1) *Bacteriological diagnosis.*
(*a*) The total number of cases in which the C.S. fluid has been examined and the number in which the presence of Gram-negative diplococci has been demonstrated.
(*b*) In what number of cases has the meningococcus been cultivated ?
(*c*) In how many cases has the C.S. fluid remained clear throughout the attack of the disease and shown no pus cells microscopically ?
(*d*) Have any cases shown a secondary infection ?

(2) *Naso-pharyngeal secretion.*
In what number of the acute cases has the presence of the meningococcus been demonstrated in the naso-pharyngeal secretion at the onset ?

(3) *Blood.*
In what number of acute cases has the blood been examined for the meningococcus, and in how many cases has meningococcus been recovered from the blood ?

(4) *Urine.*

In what number of the acute cases has the urine been examined for the meningococcus, and in how many cases has the meningococcus been recovered from the urine?

(5) *Types of meningococcus.*

What types of meningococcus, and in what proportions have they been found present in the cerebro-spinal fluid and naso-pharyngeal secretion of the cases? Have the types of meningococcus found in naso-pharyngeal secretions of contacts corresponded with the type of meningococcus recovered from the cerebro-spinal fluid? When "non-contacts" have been examined have the type of meningococcus found in the naso-pharyngeal secretion been the same or have the types of meningococcus differed? If the latter, what types have been found associated and in what proportion? Have any types of meningococcus been met with which could not be placed in any of the 1, 2, 3 and 4 types of Gordon? Has any difference been noticed in the clinical symptoms and intensity of the disease which may be attributed to the particular type of meningococcus present? Have any relations been noted between one particular type and any series of cases or any class of troops contracting the disease (*i.e.*, Australians, Canadians, R.F.C., young soldiers' battalions, etc.)? Has any relation been noted between the prevalence of one particular type and

(*a*) Season.
(*b*) Stage of outbreak.
(*c*) The topographical distribution of the disease. Has any locality been specially affected?
(*d*) Other circumstances.

In cases in which there has been failure to isolate the meningococcus from the cerebro-spinal fluid, has lymphocytosis been present, and in such instances have mumps or measles been present in the station, antecedent or subsequent to the occurrence of cases of cerebro-spinal fever?

E.—Fatality.

Number of fatal cases.
Has the fatality-rate shown any relation to:—

(1) Season.
(2) Stage of the outbreak.
(3) Treatment adopted (including kind of specific serum).
(4) Stage at which treatment began.
(5) Age.
(6) Length of service.
(7) Intensity of the infection of the disease. Has the fatality shown special incidence in relation to the topographical distribution of the disease?
(8) Overcrowding or mass infection.
(9) Complications (*e.g.*, broncho-pneumonia, hydrocephalus, etc.)
(10) Other circumstances.

Proportion of typical to atypical clinical types of the disease and the proportion of severe to mild cases.

F.—Treatment.

The results of treatment by specific serum.

(1) Observations as to the amount and frequency of the dosage.
(2) Method of administration: Observations on the use of a general anæsthetic for lumbar puncture.
(3) Observations on anaphylaxis.

(4) Has any difference in clinical potency been noted between the sera of different makers or between different brands of sera from the same maker ? Has the difference, if any, been associated with any particular type of meningococcus causing the infection ?

(5) Observations on the relation between the date of commencement of serum treatment and the results obtained. This should be shown if possible in a tabular form.

(6) Have any other methods of treatment (*e.g.*, adrenalin for fulminating cases) been employed and if so with what results ?

(7) Has routine disinfection of the naso-pharynx and mouth of the patient been practised as advocated by some authorities, and if so with what result ?

G.—Complications.

Have either panophthalmitis, nephritis, broncho-pneumonia, endocarditis, arthritis, cystitis, etc., occurred in any of the cases ? When such complications have occurred, has the meningococcus been isolated from the lachrymal fluid, urine, sputum, blood, or synovial fluid ? When orchitis has been present, has the meningococcus been isolated from the cerebro-spinal fluid, and if so what type of meningococcus was found to be present ? In such cases when the meningococcus was not isolated, was lymphocytosis present and if so, were mumps and measles definitely excluded from the diagnosis ?

H.—Carriers.

(*a*) How many contacts of cases, and how many non-contacts have been examined for the carrier condition ?

(*b*) Give the number of " carriers " found (1) among contacts of cases (2) among non-contacts.

(*c*) The relative percentage number of carriers among contacts of cases and non-contacts in relation to :—

(1) Season.
(2) Meteorological conditions.
(3) Stage of the outbreak.
(4) Housing in barracks, huts, tents, billets, etc.
(5) Overcrowding.
(6) Naso-pharyngeal abnormalities.
(7) Other circumstances.

(*d*) Result of observations made as to the occurrence of carriers among non-contacts during an outbreak or at other times.

(*e*) Have any observations been made on recruits on the day of their arrival at military stations which would tend to throw light on the carrier-rate in the civil population, or in particular towns or districts from which the recruits came, or in regard to trades and occupations in which the recruits were engaged in civil life.

(*f*) Duration of " carrying " in relation to :—

(1) Season.
(2) Meteorological conditions.
(3) Overcrowding.
(4) Naso-pharyngeal abnormalities.
(5) Other circumstances.

(*g*) Have any known carriers developed the disease ?

(*h*) Have any instances been noted in which it is clear that a carrier has conveyed the disease to others ?

(*i*) Have any observations been made on the relative positions in huts, barracks, billets, etc., of the beds of the cases and their positive contacts and the relation of the beds of both to the position of doors, windows, stoves, etc., in the hut ? If possible such observations should be illustrated by diagrams.

(j) **Treatment of the carrier.**

(1) What methods of treatment have been employed and with what results ?

(2) Observations on the use of the Levick steam spraying apparatus as a prophylactic measure against the incidence of :—

(1) Cerebro-spinal fever.
(2) Measles.
(3) Mumps.
(4) Common colds.
(5) Diphtheria.
(6) Other infectious diseases.

(3) Details concerning the use of the Levick sprayer or other spraying apparatus should be given, *i.e.*, size of chamber, ventilation of chamber between different batches of troops passed through, length of time allowed between the departure of one batch of men from the spraying chamber and the introduction of the next batch, period of exposure to steam disinfecting vapour, number of men passed through chamber at same time, nature of disinfectant used in the steam vapour, etc.

(4) The number of men passed through the spray chamber, with dates, should be given in a tabular form, the table should show clearly the number of times and on which dates any particular man passed through the chamber, and the effect of the spray treatment on the carrier rate and the incidence of the disease.

The headings given above are not intended to limit the scope of the report, but to serve as a general guide to some of the lines on which information is desired, and to assist in the tabulation of the observations of many experienced workers. It is requested that each of the points mentioned will be dealt with by the reporter, and any further observations relating to the ætiology, bacteriology and measures of administrative contiol of cerebro-spinal fever will be welcomed.

All records and remarks will be regarded as confidential, but it is hoped that they may be placed at the disposal of the War Office Committee for the purposes of ultimate use in connection with publication, if such appears desirable, in the Medical History of the War.

The reports as soon as they are completed should be forwarded through the usual channels to the D.D.M.S. of the Command for transmission to Surgeon-Colonel Reece, C.B., Room 33, Adastral House, London, E.C.4.

APPENDIX C.

PREVENTION OF CHILLED FEET AND FROSTBITE.

1.—*General Routine Orders issued to British Armies in France. Part I. Adjutant-General's Branch. G.R.O. 1275, dated 28th November, 1915.*

1. These conditions are caused by :—

(*a*) Prolonged standing in cold water or mud.
(*b*) The continual wearing of wet socks, boots, and puttees.

2. They are brought on much more rapidly when the blood circulation in the feet and legs is interfered with by the use of tight boots, tight puttees, or the wearing of anything calculated to cause constriction of the lower limbs.

3. They can be prevented or diminished by :—

(a) Improvements to trenches leading to dry standing and warmth.

(b) By reducing the time spent in the trenches as far as the military situation permits.

(c) By regimental arrangements ensuring that, so far as is possible, men enter the trenches warmly clad in dry boots, socks, trousers, and puttees, and with the skin well rubbed with whale oil or anti-frostbite grease.

(d) By provision of warm food in the trenches when possible.

(e) By movement when possible, so as to maintain blood circulation.

(f) By the provision of warmth, shelter, hot food, and facilities for washing the feet and drying wet clothes for men leaving the trenches.

4. In order to minimize the prevalence of chilled feet and frostbite, commanding officers will be held responsible that the following instructions are carried out unremittingly and under the strictest supervision :—

(a) Before entering the trenches, feet and legs will be washed and dried, then well rubbed with whale oil or anti-frostbite grease, and dry socks put on. It is of the utmost importance that whale oil or anti-frostbite grease should not merely be applied, but thoroughly rubbed in until the skin is dry. Unless this precaution is systematically carried out the oil and grease become in a great measure valueless.

(b) A second pair of dry socks will be carried by each man, and where possible, battalion arrangements will be made for socks to be dried and re-issued during each tour of duty in the trenches.

(c) While in the trenches, boots and socks will be taken off from time to time, if circumstances permit, the feet dried, well rubbed, and dry socks put on.

(d) On no account will hot water be used, nor the feet held near a fire.

(e) Where possible, hot food will be provided during tours of duty in the trenches.

(f) Where circumstances admit, long gum boots will be put on while the men's feet are dry before entering wet trenches, in order that men may start their tour of duty with dry feet.

(g) When gum boots are worn it is well to support the socks by some form of fastening such as a safety-pin, to prevent them from working down the heel. On no account will anything in the form of a garter be worn.

(h) Where conditions are favourable, regimental rest posts will be instituted in proximity to the trenches, where men who show signs of suffering from exposure can be promptly attended to.

5. Under brigade arrangements, provision will be made for the washing and drying of feet in reserve billets, for the exchanging of wet socks for dry ones, and, if possible, the sending of the latter to the trenches, and for drying and brushing clothes. Steps will be taken to ensure that men make use of these arrangements.

6. Long gum boots are being issued to the fullest extent of the supply available, and every effort will be made to procure all that are necessary for men holding waterlogged trenches. It is pointed out that the distribution of these boots depends upon the necessity for their use according to the nature of the trenches held by divisions, brigades, etc., and that, therefore, the distribution will be made not according to the numerical strength of formations, but according to the nature of the trenches which formations are required to hold.

2.—*Fourth Army Standing Orders. Part I. Adjutant-General's and Quartermaster-General's Branch. Nos. 594–599, 20th June, 1917. (France.)*

Prevention.

594. In order to minimize the occurrence of trench foot and frostbite during winter, instruction in the measures of prevention detailed below will be commenced *before* cold weather commences.

595. C.O.'s will be reminded that the loss of effective strength due to the prevalence of this trouble is an indication of faulty discipline and faulty interior economy, and they will, therefore, be held responsible that the instructions laid down are carried out under the strictest supervision by company officers.

596. Regular foot-rubbing drills will be carried out throughout the Army during inclement weather, both in and out of the trenches. Such drills improve the circulation and should be started *long* before the men have to go into the trenches.

597. The following preventive treatment will be carried out either by divisions (at the main dressing stations) or regimentally in a hut or building set apart for the purpose.

The treatment will include the use of :—

(*a*) A soap made of :—

Soft potash soap	1,000 parts.
Powdered camphor	25 ,,
Powdered sodium borate	100 ,,

(*b*) A powder composed of :—

Powdered talc	1,000 parts.
Camphor	25 ,,

A teaspoonful of the powder and ¼ oz. of soap will be required for each man.

The quantities of the ingredients required per division per week are approximately :—

Potash soap ..	300 lb.	Sodium borate ..	35 lb.
Camphor	22 ,,	Talc powder ..	500 ,,

The feet will first be washed in hot water with ordinary soap, then in hot water with the soap (*a*). They will next be carefully dried, and the nails will be attended to by the chiropodist. Particular care must be taken to clean out the grooves at the sides of the nails. Finally, the feet will be dusted with the powder (*b*), a little of which will also be dusted into the socks. The man is then ready to go into the trenches.

While in the trenches his boots and socks will be taken off at least twice a day. The men will be told off in pairs, and each man will be responsible for the feet of his comrade. He will first dry and then massage the latter's feet from the toes upwards. He will then dust some of the powder over the feet, between the toes, and into the socks. This treatment renders the feet antiseptic, gives rise to a pleasant aromatic smell of camphor, and is very popular with all ranks.

The measures detailed above will, if carried out thoroughly, reduce the numbers of cases of trench foot to a minimum, but they will not abolish them altogether.

598. Trench foot is favoured by standing in wet boots, and is aggravated by the use of tight boots, tight puttees, and the wearing of anything causing constriction of the lower limbs. Action on the following lines, in addition to the preventive treatment given above, will therefore be carefully and systematically carried out :—

(*a*) Trenches will be kept as dry as possible.

(*b*) Men in waterlogged trenches will be relieved every twenty-four hours, if possible.

(*c*) Men holding waterlogged trenches will wear gum boots. If these are not available, the ankle boot or field service boot worn should be at least two sizes too large and very loosely laced. When gum boots are worn the socks should be fastened round the ankle by a safety-pin so as to prevent them working down under the heel. No form of garter is to be worn.

(*d*) Puttees should not be worn *in the trenches*, and the tapes attached to certain patterns of drawers, to prevent the drawers from rucking up the leg, are not to be tied tightly.

(*e*) The preventive treatment will be carried out under the direct personal supervision of an officer.

(*f*) A second pair of dry socks will be carried by each man, and battalion arrangements will be made for dry clean socks to be sent up in waterproof bags daily, with the supplies, for the men in the trenches.

(*g*) While in the trenches men should be encouraged to move about as much as possible so as to maintain blood circulation. On no account will men be allowed to hold their feet near a fire or dip them in hot water.

(*h*) Arrangements will be made whereby men in the trenches can obtain warm food, hot drinks, shelter, and warmth. Where conditions are favourable regimental posts will be instituted in proximity to the trenches, where men who show signs of suffering from exposure can be attended to promptly.

(*i*) On coming out of the trenches after a tour of duty every man should remove his wet boots and socks, thoroughly dry rub the feet and put on dry socks and dry boots. Scrupulous care is to be taken to see that facilities exist, and that the men carry out these details as soon as they get into reserve billets. As much preventible harm can be done by the men hanging about in billets with sodden boots and socks as may result from hours of necessary exposure in the front trenches.

(*j*) Thigh gum boots will be allotted by the corps to divisions, and by divisions to brigades, in proportion to the number of men in the trenches. In each brigade section there will be two pairs of boots per man in the trench line, so that while half the boots are being worn by men in the trenches the other half may be cleaned, dried, and made ready for the reliefs.

(*k*) Divisions will establish one or more *gum boot stores* in each brigade section. Each gum boot store will have a changing room or shed provided with facilities for cleaning and drying the feet, and with seats for the men to use when changing their boots. The stores and changing rooms will be warmed, wherever possible, by means of hot-water pipes, which will also help to dry the boots—see (p.) (iii), below. The pipes can be heated in connection with the stoves provided for making hot drinks—see (*n*) below.

(*l*) These stores should be as near the communication trenches as possible so that men may not have to march far along high roads in gum boats.

(*m*) Men going to the trenches will draw gum boots from the gum boot store, and leave their ankle boots at the store, unless the tactical considerations at the moment make it necessary for them to keep their ankle-boots with them.

(*n*) Men coming out of the trenches will leave their gum boots at the gum boot store and receive their ankle boots from the store, unless they have them with them. The men will change their boots without delay, and should then be provided with hot soup, tea, coffee or cocoa.

(*o*) The gum boot store in each section will be under the supervision of the brigade occupying the section for the time being.

(*p*) A selected N.C.O. with a small well-organized staff will be placed in *permanent* charge of each gum boot store. He will be responsible for :—

(i) The issue and receipt of gum boots to and from units.

(ii) The marking with chalk and tying together in pairs of the boots taken off, so that they can be handed back without delay to their owners when the latter return from the trenches.

(iii) The cleaning, drying, and repairing of gum boots in store, so as to have them ready for issue to the next relief.

The drying of gum boots is a difficult matter, *and very definite instructions on the subject must be given to the N.C.O. and his staff.*

The boots can be dried by hand, by means of a dry and, if possible, warm cloth, which must be worked down to the very toe. The boots must then be stood *upright* and open so as to facilitate further drying. *They must never* be hung upside down, because in that position the moisture collects inside the toe of the boot.

The following method has also been tried successfully. Place a piece or iron piping about 6 ft. long across a lighted brazier. Fit a length of rubber tubing to one end of the iron piping, and the nozzle (which should fit closely) of a hand bellows to the other end. When the iron piping is hot, blow hot air into the boots. The rubber tubing will carry the hot air right to the toe end of the boot.

Some sort of drying powder, innocuous to the boots, such as equal parts of starch and boric acid powder, should be dusted into the boots when they are placed ready for use. If starch and boric acid powder are unobtainable, chopped hay, straw, or chaff may be used to dry the boots, and the same supply can be used repeatedly, if dried.

(iv) The demanding (through brigade headquarters) of new gum boots as necessary.

(v) The cleaning, drying, and greasing of the ankle boots left at the store by the men in the trenches.

(*q*) An inventory will be kept at each gum boot store showing the number of boots allotted to that store and recording all permanent transactions such as the return of unserviceable boots to D.A.D.O.S., the receipt of new boots in replacement, and any transfer of boots from one store to another.

(*r*) As gum boots wear out the unserviceable ones will be handed in to the D.A.D.O.S., and an equivalent number of new ones will be demanded in replacement.

(*s*) Thigh gum boots are trench stores, and men will not be allowed to take back to billets the gum boots issued to them for trench wear.

3.—*The Organization and Administration of "Footwashing Centres for the Prevention of Trench Foot," in France during the Winter of 1917–18.*

The following note is a brief account of the arrangements for carrying out the French method of preventing "trench foot," which was adopted by some of the British divisions in France when those formations were actually in the line, during the winter of 1917–18. No oily or greasy preparations are used in this method, which is much more cleanly and efficient than the inunction of whale oil.

(1) The possibility of wastage from trench foot assuming serious proportions was always a source of considerable anxiety ; and notwithstanding the issue of very clear orders and instructions from general headquarters as to how the disease could be combated, the means for giving effect to the measures recommended often presented considerable local difficulties.

(2) At first one centre was established which could deal with a battalion in a working day of eight hours; the experiment was a success, so it was decided in future to have two centres for the division when in the line—one for the right and one for the left brigade. The principle followed was to locate these washing centres as near as possible to the trenches in order to inconvenience the men as little as possible and with due regard to a reasonable degree of safety.

(3) The centres were established in ruined buildings or huts as circumstances permitted. Fig. 1 indicates the general arrangements in a hut.

Four wooden troughs, approximately 10 ft. long by 1½ ft. broad by 1 ft. deep, were fixed into the wooden floor of the hut, and were placed so that they sloped towards the centre of the building, to allow the dirty water to escape through the outlets B, thence, via a channel A, clear of the hut to a soakage pit.

Nail-brushes were provided and fixed by a length of string to the sides of the wooden troughs.

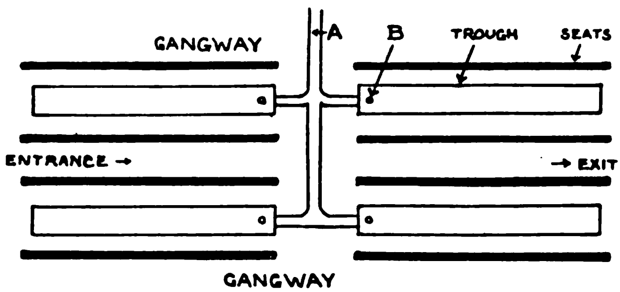

Fig. 1.—Diagram showing seats and troughs on the floor of a "Foot Washing Centre."

Supply of Hot Water.—Arrangements were made for two or three Soyer stoves, a supply of fuel, a water-cart and a couple of buckets, medicated soft soap, nail scissors, a supply of clean socks powdered on the inside, and foot powder in suitable tins with perforated lids.

When there was no available building or hut foot-washing centres were organized in the ordinary store tent with trench boards for flooring, and tubs when there were no special troughs.

(4) *Personnel.*—The personnel required consisted of :—

1 N.C.O. in charge and to supervise the issue of soap and powder.
1 man in charge of socks.
1 ,, ,, stoves for hot water.
1 ,, with the water-cart.
1 ,, general duty.

(5) *Procedure.*—A programme or time-table was issued the previous day, and instructions were issued for the men (who bring their own towels) to report at the centre in batches of forty every twenty minutes, commencing at 8 a.m.

On arrival, the party of men take off their puttees, remove the boots and socks, and put their bare feet into their boots while still outside the building; then, carrying their puttees and dirty socks they file into the room, dropping their dirty socks into sacks at the door.

They then sit down on the benches, and a portion of medicated soap is served out to each man who then thoroughly washes his feet with the warm water and nail-brushes provided. The men then dry their feet and attend to their nails. After inspection by the medical officers and chiropodist an attendant dusts the feet with the powder and the men put on clean powdered socks and their boots, then file outside of the building where boots are laced up and puttees adjusted. The dirty water is changed for the next batch.

(6) Both divisional, brigade and unit commanders were much impressed with the obvious utility of the scheme, and the facilities for cleansing and attending to their feet were much appreciated by the men.

Clean Socks in the Trenches.—Arrangements were made for clean powdered socks to be sent up with the rations to the trenches every night so that every man could have a change of socks every twenty-four hours while actually in the line. In addition, each company was provided with tins of powder for dusting the feet, and a reserve of this powder was kept at the advanced dressing stations.

The composition of the medicated soap was as follows :—

Soft soap	1,000 parts.
Powdered camphor	25 ,,
Powdered borax	100 ,,

The foot powder consisted of :—

Talc	1,000 parts.
Camphor	25 ,,

4.—*Instructions issued in Salonika for the Prevention of Frostbite and Trench Foot.*

Frostbite is caused by excessive freezing cold which stops the circulation of blood in the feet. It is hastened by anything tight about the feet or legs, and may also affect the tips of the fingers, ears, and nose, if these are exposed during very great cold and wind.

Trench foot is a condition not unlike frostbite, but may be caused when cold is neither excessive nor freezing, if boots and puttees are kept tightly on for days at a time when standing in wet and cold trenches, as the wet and cold added to the tightness of boots and puttees kept on for a long time have exactly the same effect as the stopping of the circulation of the blood by a freezing cold.

Both frostbite and trench foot are so serious that they may cause a man to lose his feet altogether.

The following rules must therefore be observed by every soldier in order to prevent these serious conditions :—

(1) Do not keep boots tightly laced, or puttees tightly worn round the leg.

(2) Take boots and puttees off altogether, rub and dry feet, and put on dry socks at least once in twenty-four hours. In ordinary circumstances there should always be an opportunity for doing this.

(3) Always obtain a large size of boots, but do not put on two pairs of socks to prevent cold, if by so doing the boots are made tight on the feet.

(4) Always carry with you one pair of dry socks to put on in exchange for wet ones.

(5) If you can sleep with your boots off do so, wrapping your feet in newspapers or blankets, or, if obtainable, dry straw, hay, or suchlike material. In any case, never sleep with your boots tightly laced, keep them loose, and your puttees loose, when you lie down to sleep.

These rules are the most important measures of all for the prevention of frostbite and trench foot, but the following additional rules should also be attended to :—

(6) Grease or dubbin your boots well to prevent them becoming sodden with wet.

(7) Whenever there is a feeling of numbness in the feet remove your boots at once and commence rubbing your feet until sensation returns.

(8) Never put numbed feet before a fire or into hot water.

(9) Grease, oil, and similar preparations rubbed on the feet or socks help to keep out wet and cold but do not prevent frostbite or trench foot so long as boots and puttees are kept tight on the feet and for a long time without being removed.

(10) The body should be kept as warm as possible by exercise, movement, and warm clothing.

H.Q. Force, Salonika, 21st December, 1915. — Director of Medical Services, Salonika Force.

The above instructions are to be circulated as freely as the number of copies printed will admit, and are to be read three times weekly on parade to all troops. Arrangements are to be made by frequent inspections to see that the measures advocated are strictly complied with.

A.H.Q., Salonika, 21st December, 1915. — D.A. & Q.M.G.

APPENDIX D.

SMALLPOX.

1.—*Memorandum on the Diagnosis of Smallpox.*

This disease can be controlled completely by means of prompt isolation and general vaccination ; but prompt isolation demands a prompt diagnosis of the disease. As many medical officers have not had opportunities of becoming sufficiently familiar with the subject, it may be of service to set out the main clinical features of smallpox and those which more particularly serve to distinguish it from diseases with which it may be confounded.

A typical case of smallpox presents the following symptoms : After an incubation period of twelve days the patient *suddenly* develops high fever (usually 102° to 104° F.), accompanied by vomiting, pain in the back, head and limbs, and marked prostration. During the first two days these symptoms may be attended by certain initial rashes, which usually take one of the two following forms :—

(1) A widespread, rapidly advancing erythema of the trunk or limbs, which may disappear in twenty-four to forty-eight hours. Such a rash may be scarlatiniform, morbilliform, or occasionally urticarial ; and it is always associated with a mild attack.

(2) A strongly marked, closely localized petechial rash, occurring especially in and about the groins, persisting usually for three or four days and associated with a severe initial attack.

On or about the third day of attack the temperature falls, and a marked improvement in the condition of the patient sets in. The characteristic eruption then appears, usually first on the face, wrist and hands, and later on the trunk and legs. The tiny soft red spots, faintly seen at first, develop in twenty-four hours to firm papules and at the end of forty-eight hours these begin to develop vesicles. Generally at the end of ninety-six hours the rash is fully vesicular, with pustules beginning to show, and later these pustules rupture, discharge, and scab. Umbilication is a phenomenon which occurs between the middle of the papular and the middle of the pustular stage. As the rash may appear on the face thirty-six hours before it does so on the feet, it is not uncommon to find vesicles on the former while on the latter the rash is wholly papular. The lesions are sometimes so numerous as to coalesce on the face, when the disease is termed " confluent."

Many attacks of smallpox do not conform to type, owing to the effect of vaccination. Then the rash may abort at any stage; or it may run the normal length of its course with but mild lesions, which are specially in evidence on the face and hands. But often in these cases the initial constitutional symptoms are almost as severe as in typical cases of smallpox.

The Differential Diagnosis of Smallpox.—This is often attended by much difficulty, and the following points may usefully be borne in mind.

When the early symptoms, namely, sudden onset of high fever, vomiting, headache, backache, and marked prostration are accompanied by—

(*a*) A petechial rash limited to the groins and axillæ—smallpox is almost certainly present.

(*b*) A purpuric rash—smallpox or purpura may be present. When the purpura is accompanied by bleeding from the mucous membranes, hæmorrhages under the conjunctivæ, and great prostration, the case is almost certainly one of hæmorrhagic smallpox; and this diagnosis is confirmed if elements of the papular rash (however small and soft) are discernible.

(*c*) A general scarlatiniform rash—smallpox or scarlet fever may be present. Severe backache with pains passing round to the epigastrium greatly favour the diagnosis of smallpox; while circumoral pallor, strawberry tongue, intensely injected fauces and enlarged glands are indicative of scarlet fever. In the early stages of smallpox the pharyngeal and oral mucous membranes are either unaffected or show bright red macules, of about the size of a split pea, which rapidly pass into erosions.

(*d*) A morbilliform rash—smallpox or measles may be present. The catarrhal symptoms and cough of measles are absent or relatively slight in smallpox, and in smallpox the initial erythema is not usually seen on the face. The rash in measles appears on the fourth or fifth day of illness; it generally appears first and is always much in evidence on the face; it is never markedly shotty, and its onset is usually accompanied by a rise in temperature and an exacerbation of symptoms; and the soft palate and fauces do not show macules and vesicles, though they may be mottled by some injection.

N.B.—In measles, Koplik's or Filatow's spots are only found on the mucous membrane of the cheeks and gums.

Chicken-pox is often confounded with smallpox, and *vice versa*. Early severe constitutional symptoms are in favour of smallpox; but chicken-pox in adults is apt to produce severe symptoms also. In smallpox the rash is usually more uniform in its stages of development, although it must be remembered that the rash on the face may be thirty-six hours in advance of that on the feet; in chicken-pox, however, it is common to see lesions in the same area at every stage of development from papule to scab. In varicella, umbilication, as in smallpox, may sometimes occur, but this is usually due to the collapse of a vesicle and not to the presence of internal ties as is the case with the smallpox vesicle; it may also occur when a chicken-pox vesicle develops around a hair-follicle or sweat-duct, or when pseudo-umbilication results from the early central scabbing of a vesicle. When it appears impossible to decide which disease is present, the progress of the rash for even twenty-four hours may clear up the diagnosis. Meanwhile the case should be isolated as if it were smallpox. A most useful guidance may also be obtained from noting the more superficial position of the elements of the rash in varicella (this is best appreciated when a fold of the skin of the trunk is rolled between the finger and thumb). An examination of the relative distribution of the rash is always of considerable value. The patient should be stripped to the waist and inspected with the forearms crossed in front. In smallpox the rash is usually relatively abundant on the face, sparse on the chest, and well marked on the forearms and hands; in chicken-pox the rash is rarely abundant on the face, it is usually very light on the forearms and even absent on the wrists and hands.

The diagnosis from acne vulgaris, eczema, herpes, urticaria, impetigo, sycosis, lichen, scabies, syphilitic rashes, glanders, typhus, and other rashes should be possible from a consideration of the distribution of the rash, its characters, the degree of severity of the early constitutional symptoms, and the history of the symptoms.

You are advised in every case to see *all* the rash, especially that on the back and front of the trunk; afterwards to obtain as clear a history as possible; and then to base your diagnosis rather on a combination of material evidence than upon any one symptom. It is particularly to be noted that the severe early constitutional symptoms and the distribution of the rash are matters of outstanding importance in the diagnosis of smallpox. The distribution of the eruption favours the face and extremities and is generally more marked on the back than on the front of the trunk. Many mistakes are due to a disregard of the importance of the severe initial symptoms, namely, those which consist of a marked general prostration, mental dullness with lack of expression, interest, or concern. A papular, vesicular, or pustular eruption, not preceded by such symptoms, is unlikely to be smallpox.

It is expected that the responsible medical officer will have thought out beforehand and planned all necessary arrangements so that when he is called upon to deal with an outbreak of smallpox amongst troops there will be no delay that could have been prevented by foresight. For instance, those listed as available for nursing duties, or for assisting in disinfection and the removal of sufferers, will be persons who are known to have been successfully vaccinated or re-vaccinated within five years; and the separate provision to be made for the isolation of sufferers and of suspects demanding further observation, and for temporarily dealing with contacts, will have been determined. It is important to secure the immediate vaccination of those contacts who have not been successfully vaccinated within two years. When this has been secured, in addition to the obvious further precautions as to disinfection of clothing and bedding and the taking of hot baths, arrangements are necessary for the detention of contacts in the same camp or locality, and for their medical inspection every twenty-four hours for eleven days after the date of successful vaccination, and for eighteen days subsequent to exposure to infection if there is any doubt about the success of vaccination. The frequent medical inspection of all the men in the infected camp or locality when smallpox threatens is also desirable. At the earliest possible moment the medical officer should place himself in communication with the local civil medical officer of health, notifying the case to him. The latter will then be able to give valuable assistance in tracing the source of infection, in providing hospital treatment for the smallpox patients, and in the disinfection of bedding, etc., if this is required.

War Office, S.W.,
27th May, 1916.

2.—*Instructions to Vaccinators.*

1. The medical officer must ascertain whether the soldier is in a fit and proper state of health to be vaccinated.

2. The lymph used for vaccination must be used within a week of its receipt; in the interval the lymph should be kept in a cool place.

3. The medical officer must keep such record of the lymph he uses for vaccinating as will enable him always to identify the lymph used in such operation.

4. The vaccination should be performed by an instrument of such a character and in such a way as will obviate the drawing of blood; a lancet with a metal handle or a needle may be used. *The handle of the instrument should not be used for rubbing in the lymph.*

5. The instrument should be sterilized by first placing it in methylated spirit and afterwards passing it through the flame.

6. The medical officer must keep in good condition the lancets or other instruments which he uses. When he vaccinates he must cleanse and sterilize his instrument after one operation before proceeding to another. When once he has unsealed a tube of lymph he must *never* attempt to keep any part of its contents for the purposes of vaccination on a future occasion. The tube should be broken with a sterilized forceps. Under no circumstances should the mouth be applied directly to the tube in which the lymph is contained for the purpose of expelling the lymph; an artificial expeller must be used for this purpose.

7. Vaccination should at every stage be carried out with aseptic precautions. These should include: 1st, the cleansing of the surface of the skin before vaccination; 2nd, the use of sterilized instruments; and 3rd, the protection of the vaccinated surface against extraneous infection both on the performance of the operation and subsequently.

8. The site for vaccination should be on the upper arm, not lower than the insertion of the deltoid muscle.

9. The cleansing of the skin should be carried out as follows:—

(*a*) Wash the surface of the arm thoroughly with soap and hot water and then dry it with a sterilized towel, sterilized lint, or wool.

(*b*) Wash the cleansed area with alcohol.

(*c*) Wash the same area with sterilized water.

10. A protective covering must be applied in such a manner that the vaccinated surface is not tightly constricted. Boric lint cut into pieces 2½ in. square forms a suitable protective dressing, which should be kept in position by means of strips of adhesive zinc oxide plaster. Bandages should not be used for the purpose.

11. The vaccinated person must be instructed to report himself or herself immediately if the protective dressing has slipped, that is, if any of the vaccinated surface has become exposed.

12. Vaccinated cases should be dealt with as out-patients, and, if necessary, seen daily; this is particularly important from the fifth to the tenth day, during which period the arm should be kept in a sling.

13. *If the protective dressing adheres to any part of the vaccinated surface it must be removed with the utmost care*, sterilized water being used for this purpose. The arm should be redressed at intervals as required in each case until the vaccinated area has healed.

14. In all cases of vaccination the medical officer must aim at producing four separate good-sized vesicles or groups of vesicles at least ½ in. from one another. The total area of vesiculation resulting from the vaccination should not be less than half a square inch.

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